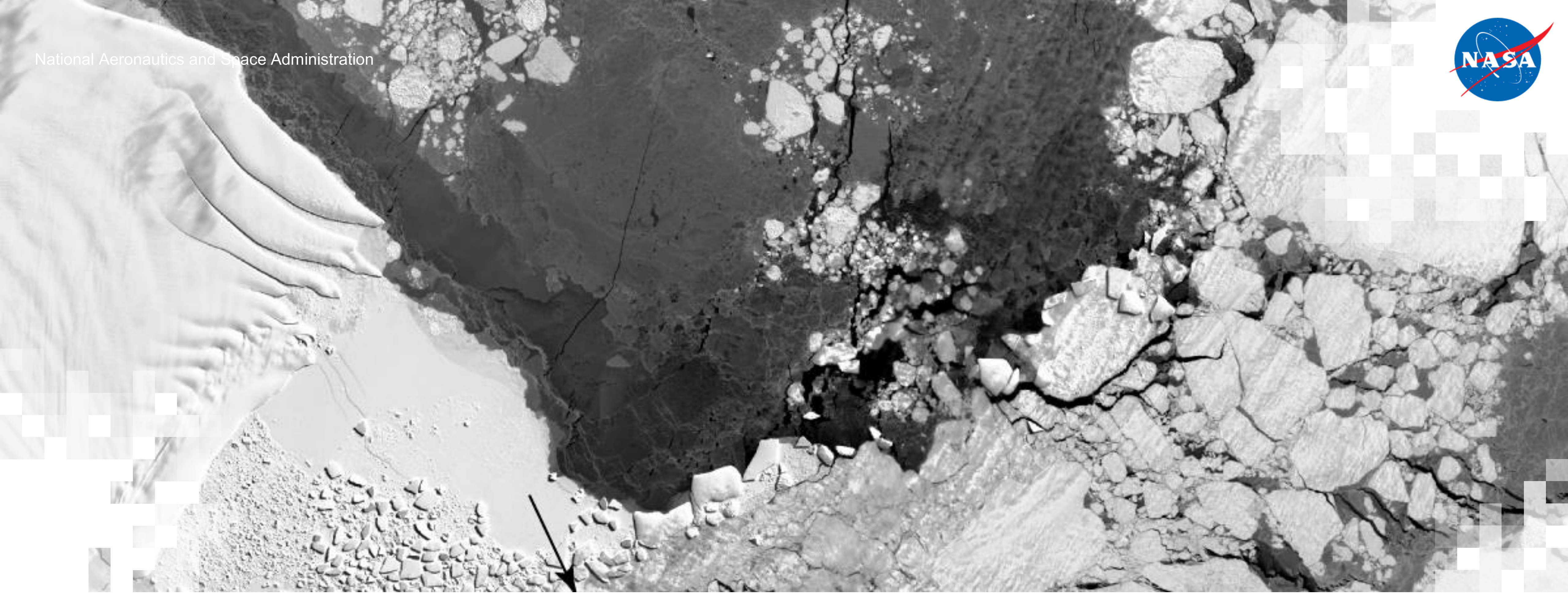
National Aeronautics and Space Administration

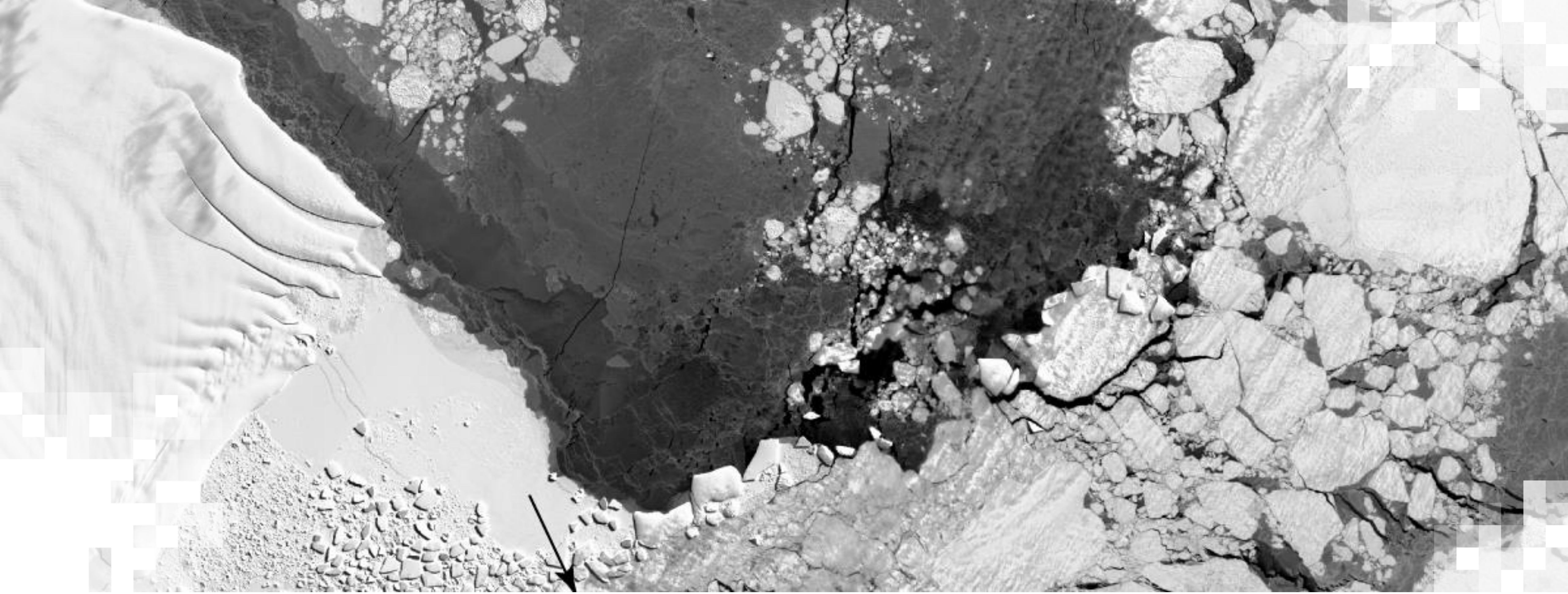


SAR for Detecting and Monitoring Floods, Sea Ice, and Subsidence from Groundwater Extraction

Session 3: Detecting and Monitoring Floods with SAR

Franz J Meyer (University of Alaska Fairbanks)

Nov 01, 2023



SAR for Detecting and Monitoring Floods, Sea Ice, and Subsidence from Groundwater Extraction

Overview

Sea Ice, Floods and Groundwater Extraction can be Seen from Space

- The objective of this webinar series is for participants to learn how to use SAR to detect and address potential disasters related to sea ice, floods and groundwater extraction.

- These sort of events can have a large impact on human lives, infrastructure and the economy.

- SAR can be critical in informing on-the-ground efforts on disaster mitigation efforts and resilience.

Training Learning Objectives

By the end of this webinar series, participants will be able to:

- Generate subsidence maps due to groundwater extraction to inform risk and resource management.

- Detect and monitor sea ice to identify potential risks to shipping and coastal erosion.

- Detect and monitor floods in order to more closely monitor increase/decrease of flood waters and better inform disaster response and management.

Training Outline

Session 1

Detecting and Monitoring Sea Ice with SAR

Tue. Oct. 24, 2023

11:00-13:00 EDT (UTC-4)

Session 2

Measuring Surface Subsidence due to Groundwater Extraction with InSAR

Tue. Oct. 31, 2023

11:00-13:00 EDT (UTC-4)

Session 3

Detecting and Monitoring Floods with SAR

Wed. Nov. 1, 2023

11:00-13:00 EDT (UTC-4)

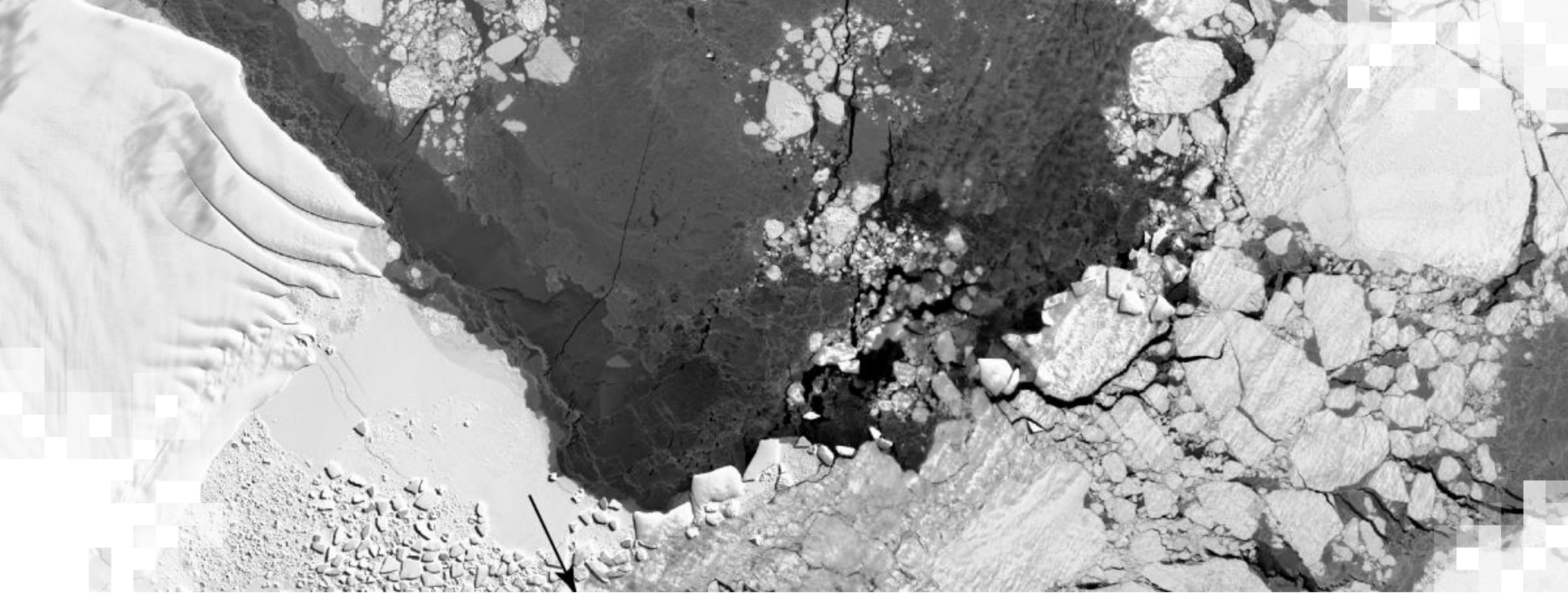
Homework

Opens Nov. 1– Due Nov. 17 – Posted on Training Webpage

A certificate of completion will be awarded to those who attend all live sessions and complete the homework assignment(s) before the given due date.

How to Ask Questions

- Please put your questions in the Questions box. It is located at the bottom right under the three points. We will address them at the end of the webinar.
- Feel free to enter your questions as we go. We will try to get to all of the questions during the Q&A session after the webinar.
- The remainder of the questions will be answered in the Q&A document, which will be posted to the training website about a week after the training.



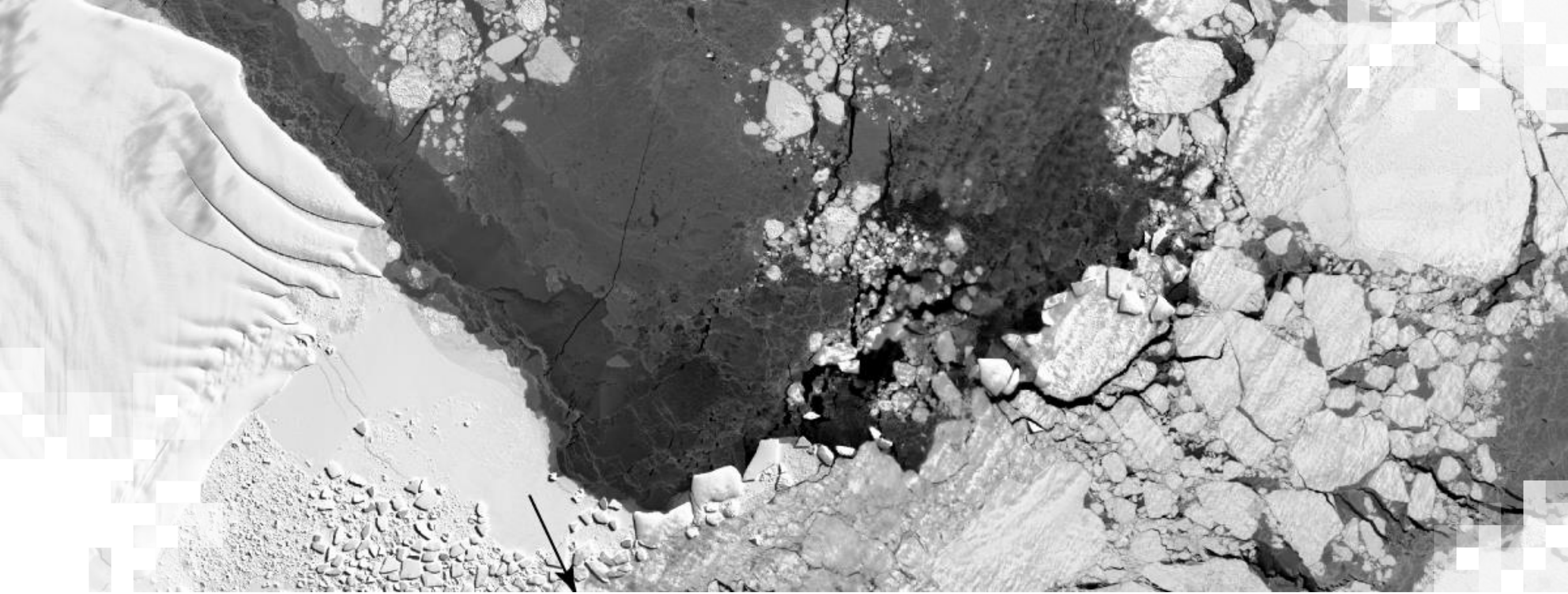
Session 3:

Detecting and Monitoring Floods with SAR

Session 3 Objectives

By the end of Part 3, participants will be able to:

- Know the properties and benefits of Sentinel-1 and NISAR for flood mapping
- Understand how different land cover types appear in SAR images and how water surfaces can be distinguished from other surface types
- Understand how to identify open water areas using thresholding algorithms
- Run a threshold-based flood mapping algorithm in a Jupyter notebook
- Know the capabilities and limitations of threshold algorithms



The Perfect Time to Learn About SAR

Sentinel-1 and NISAR: Sensor Characteristics and Where to Access Data

New Sensors & Free-And-Open Regularly-Sampled Data Provide Excellent Basis for Hazard Monitoring from SAR

Sentinel-1

esa

Frequency: C-band

Launch Date: 2015 & 16

NISAR

NISAR
NASA - ISRO SAR Mission

NASA

Frequency: L-band

Launch Date: Spring 2023

TanDEM-L

DLR

Frequency: L-band

Launch Date: TBD

2017 Bangladesh Monsoon Flooding

Copyright contains modified Copernicus Sentinel data (2017) processed by Franz J Meyer on https://opensarlab.asf.alaska.edu/

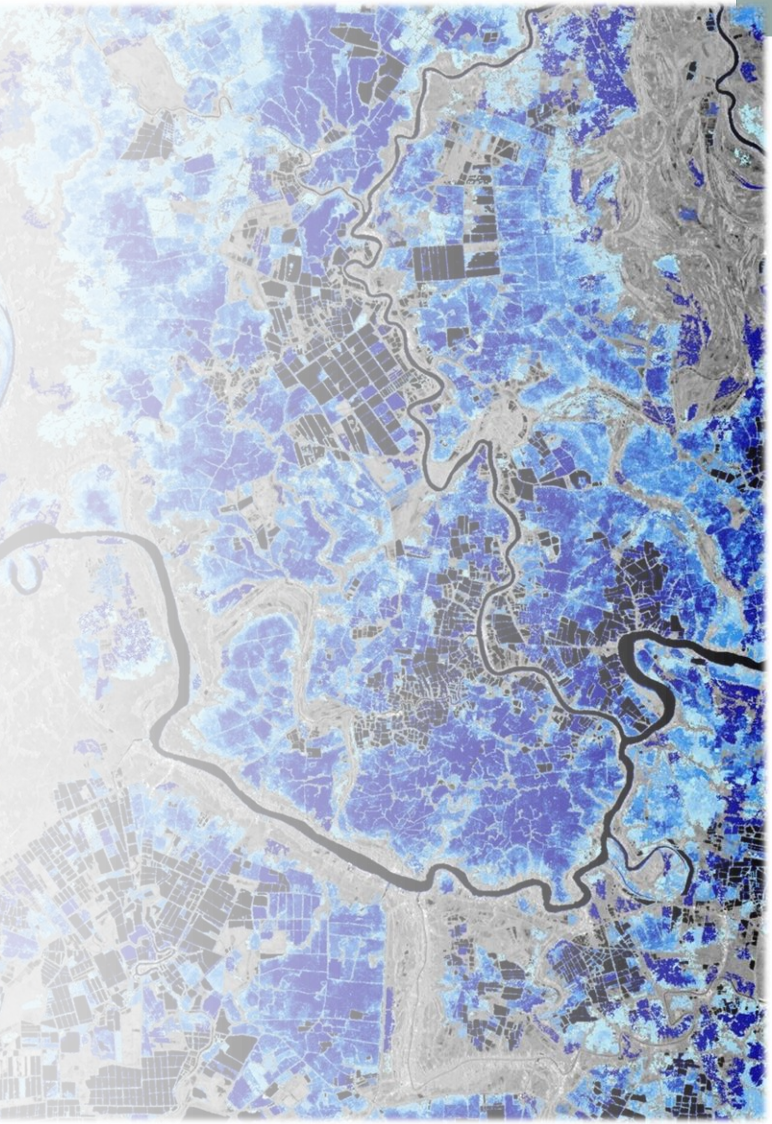
Free and Open Data!

- **Sentinel-1 (2014 - Today): First SAR Satellite System with Operational Mission**
  - Regular reliable observation according to operational requirements
  - Imaging all landmasses, coastal zones and shipping routes every six days
  - Specifically designed for InSAR

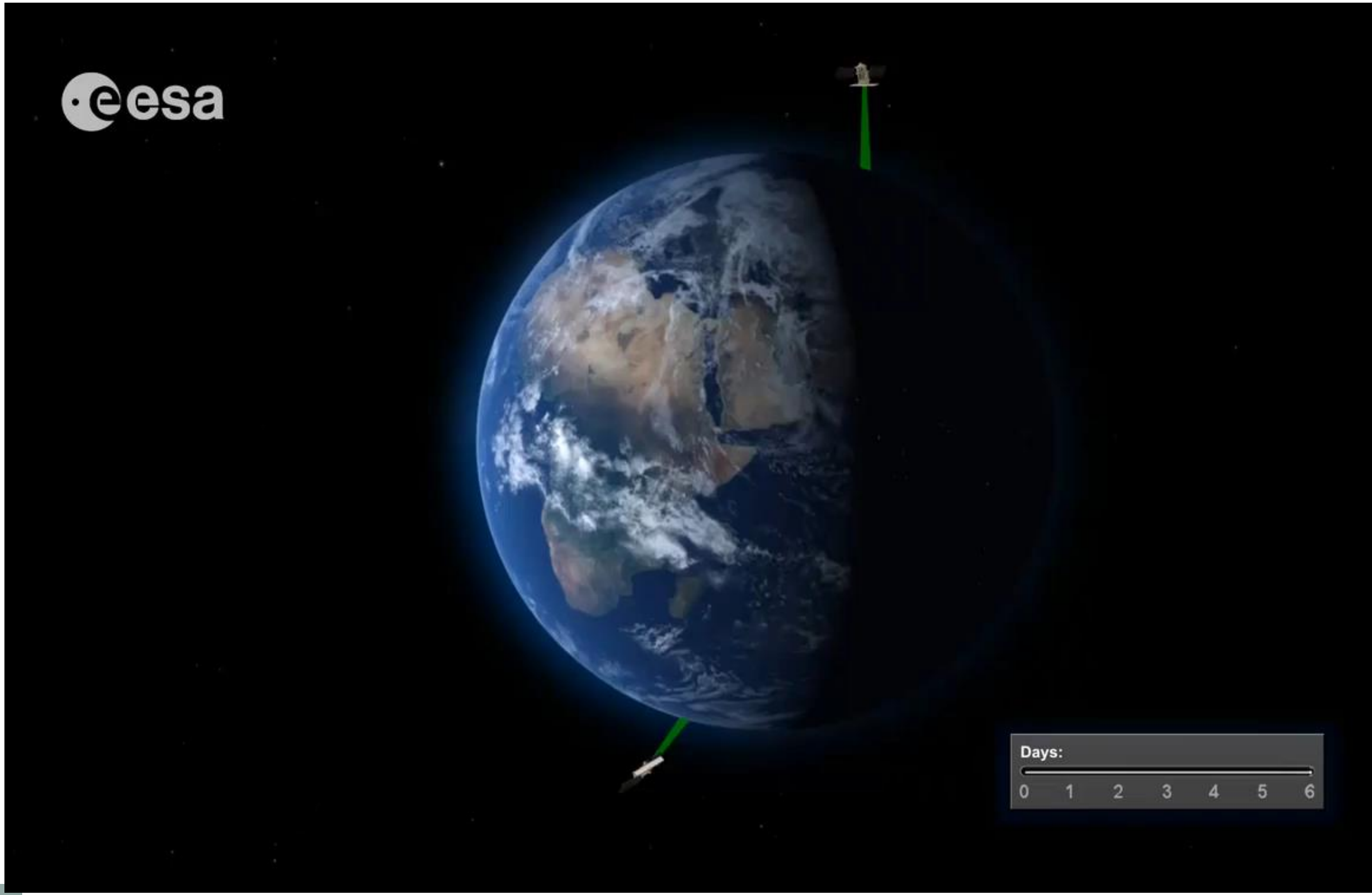
THE ESA SENTINEL-1 SAR SENSOR CONSTELLATION

The Sentinel-1 Constellation

- Launched by the European Space Agency (ESA)
- Free-and-open, globally & regularly acquired, weather-independent Earth observation data
- Constellation of two C-band SAR Sensors
  - **C-Band**: 5.6cm wavelength
  - **Polarization**: dual pol (VV/VH over land; HH/HV over ice)
  - **Image Size and Resolution**: 250km swath; 5mx20m resolution
  - **6-day temporal coverage** over Europe; 12-days elsewhere
  - **Imaging** and **interferometry** capability



Sentinel-1 Constellation – Acquisition Concept



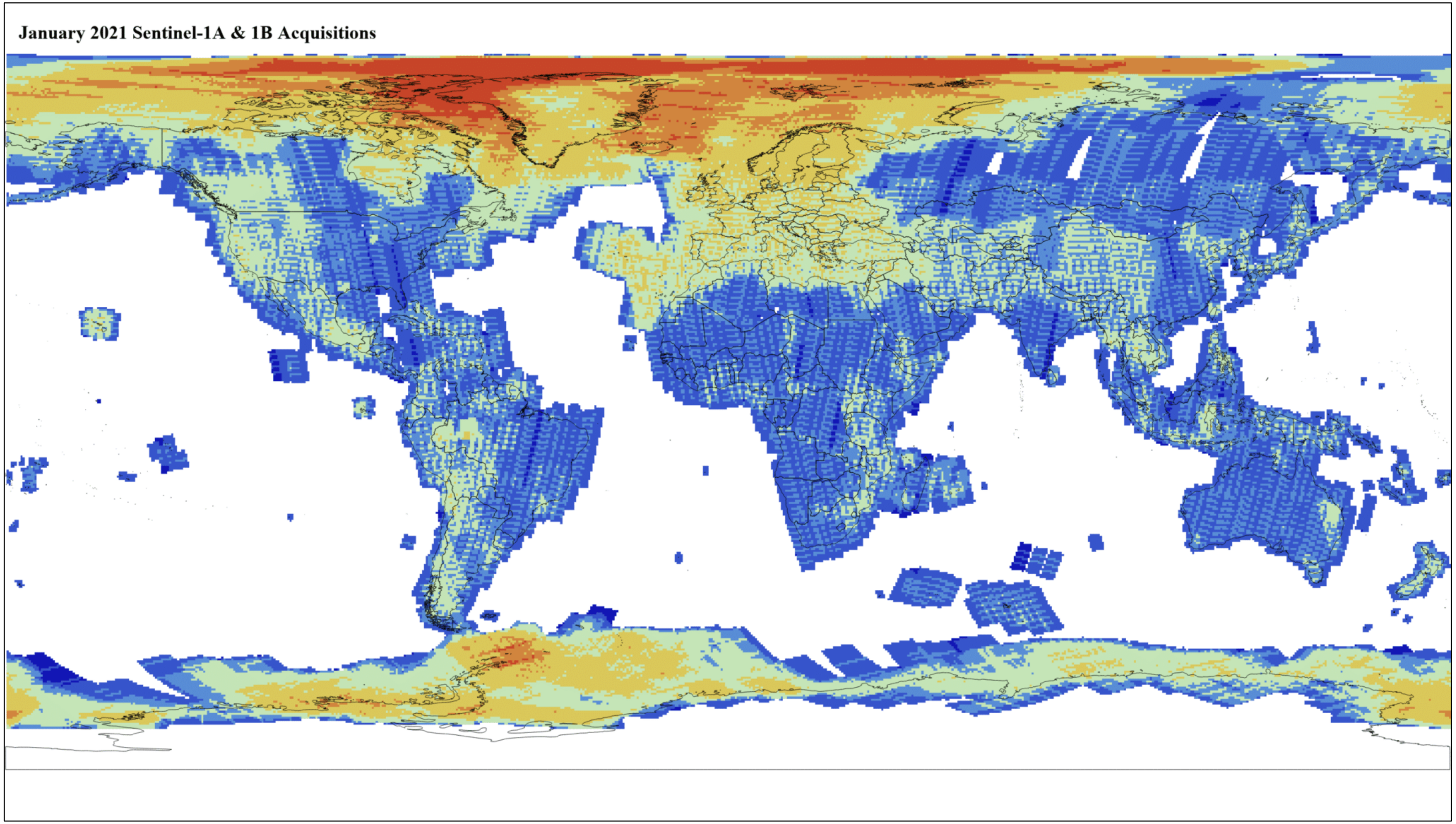
- Sentinel-1 is a constellation of two sensors to achieve 6-day sampling.
- Unfortunately, Sentinel-1B had a failure in Dec 2021, resulting in reduced imaging capacity.
- Replacement satellite Sentinel-1C planned for 2024.

Sentinel-1 Global Coverage Maps

Year 2021

2021 Coverage Maps

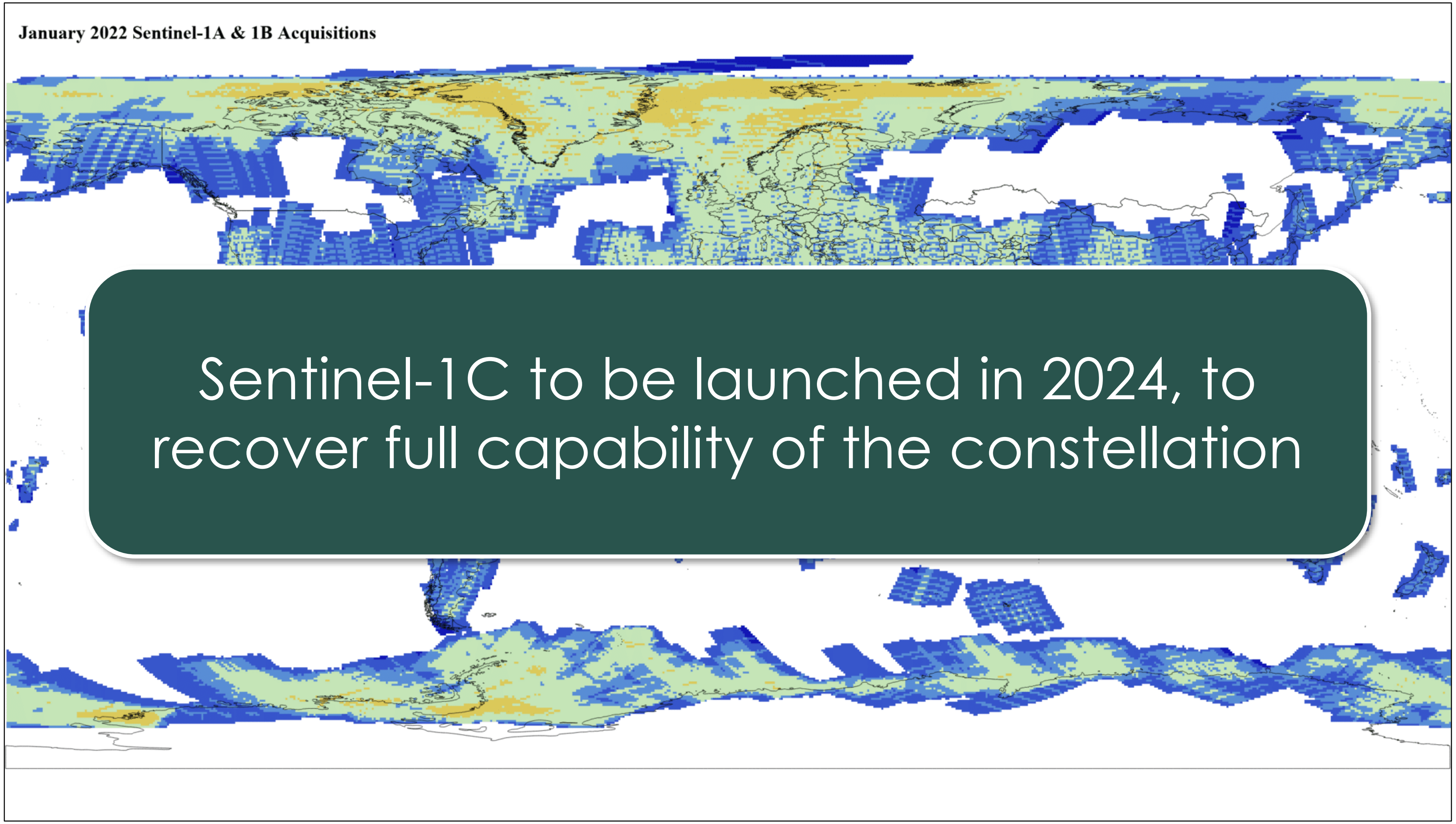
- Combined coverage from Sentinel-1A and -1B
- 6-day coverage over Europe and some hazard regions
- Maximum coverage over Arctic Ocean
- 12-day coverage elsewhere



Sentinel-1 Global Coverage Maps
Year 2022

2022 Coverage Maps

- Coverage only by Sentinel-1A after failure of Sentinel-1B in Dec 2021
- Reduced temporal coverage globally including HKH
- Coverage holes over Siberia, Canada, South America, and Africa



Sentinel-1C to be launched in 2024, to recover full capability of the constellation


THE NASA-ISRO SAR (NISAR) MISSION

Preparation for NASA-ISRO SAR (NISAR) Radar Earth Observation Satellite Project

Launch: Spring 2024

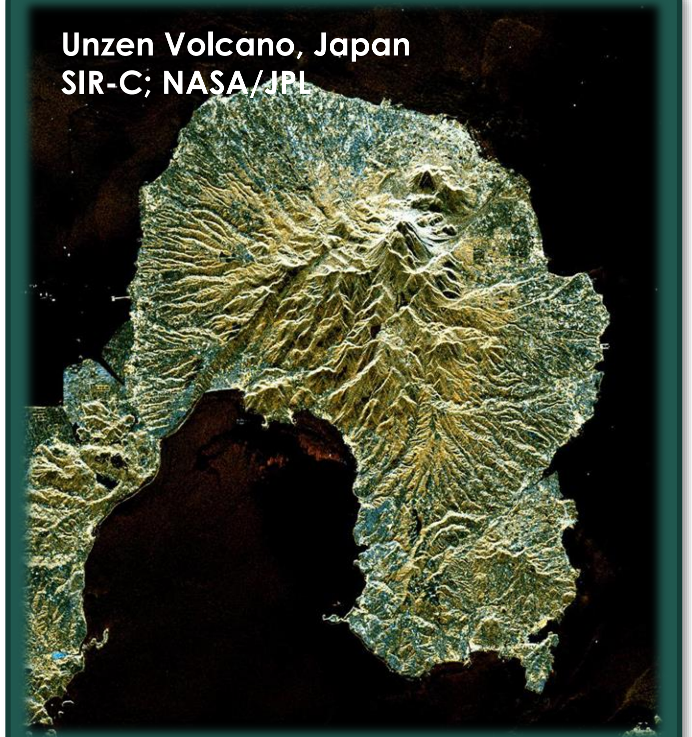
First spaceborne L- and S-band SAR

Full global coverage in 12 days

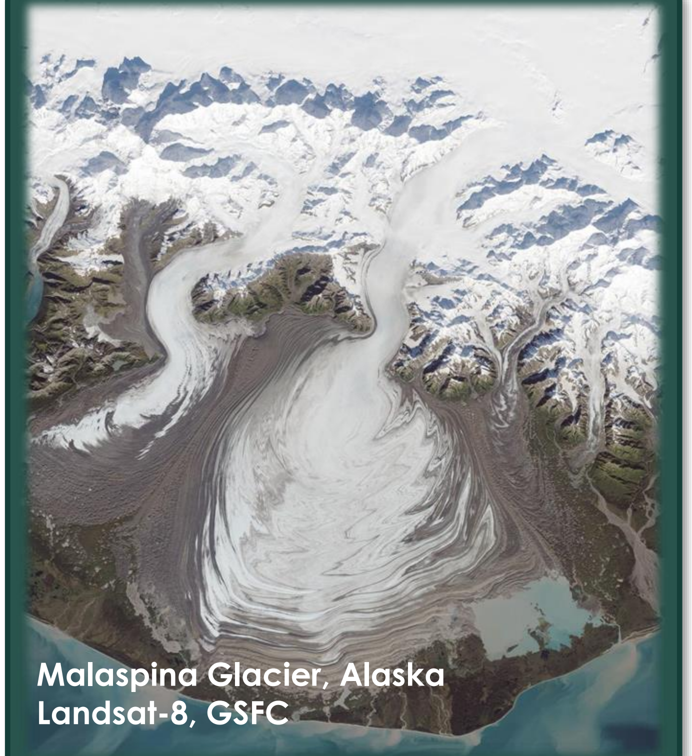
150 Petabytes of Earth Observation data/year

All Data Free and Open!

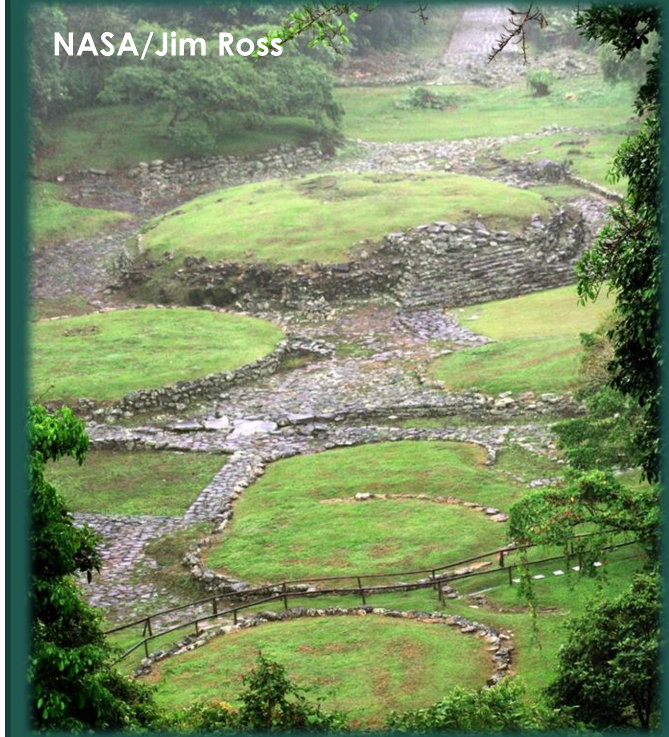
NISAR Will Provide Data for a Wide Range Of Science And Applications Disciplines



Solid Earth Science
(Earthquakes, Volcanoes, Landslides, …)



Cryospheric Science
(Glaciers, Sea Ice, Ice Sheets)



Ecosystems Science
(Forest Biomass, Agriculture, Wetland Monitoring)

The NASA Alaska Satellite Facility (ASF) DAAC

Tour Access Point to NISAR and Sentinel-1 Data

- **ASF is NASA Distributed Active Archive Center (DAAC) for Synthetic Aperture Radar Data**
  – Established in 1991 as the prime U.S. downlink and processing center for SAR data
  – Operates 4 antennas for NASA and non-NASA remote sensing satellite systems
- **Currently, ASF is housing about 20PB of SAR data in its archives, most of which in the Amazon Web Service Cloud → All data available for immediate download.**

SCAN ME

45 Years of SAR Data (Since '78)
https://search.asf.alaska.edu

NISAR DAAC (all L0 – L2 data)

Host of
Global Sentinel-1 Archive

OPERA

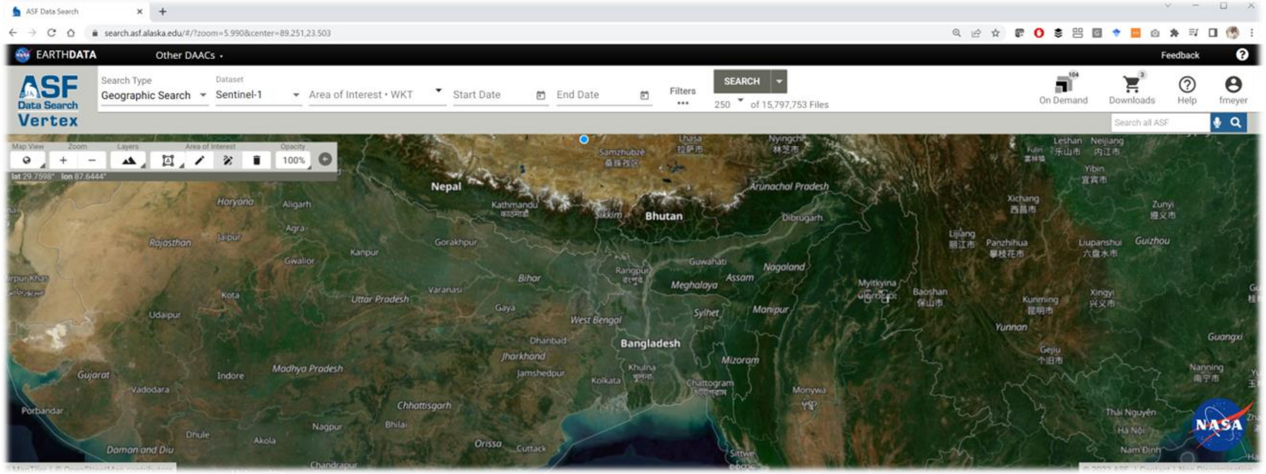
Host of **OPERA CSLC, RTC, & Displacement Data**

Visit ASF @ www.asf.alaska.edu

How To Find Sentinel-1 and NISAR Data at ASF

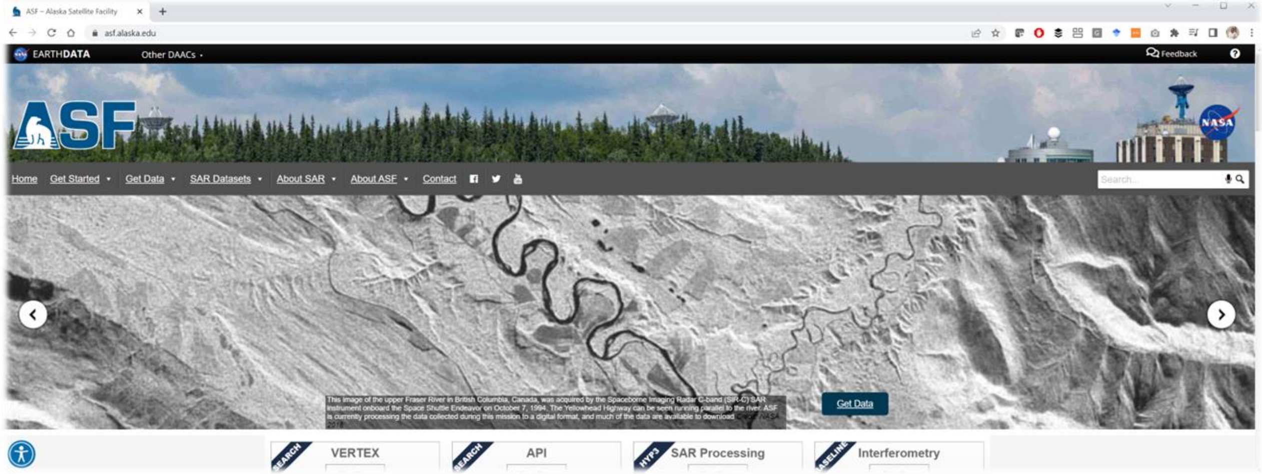
ASF Search

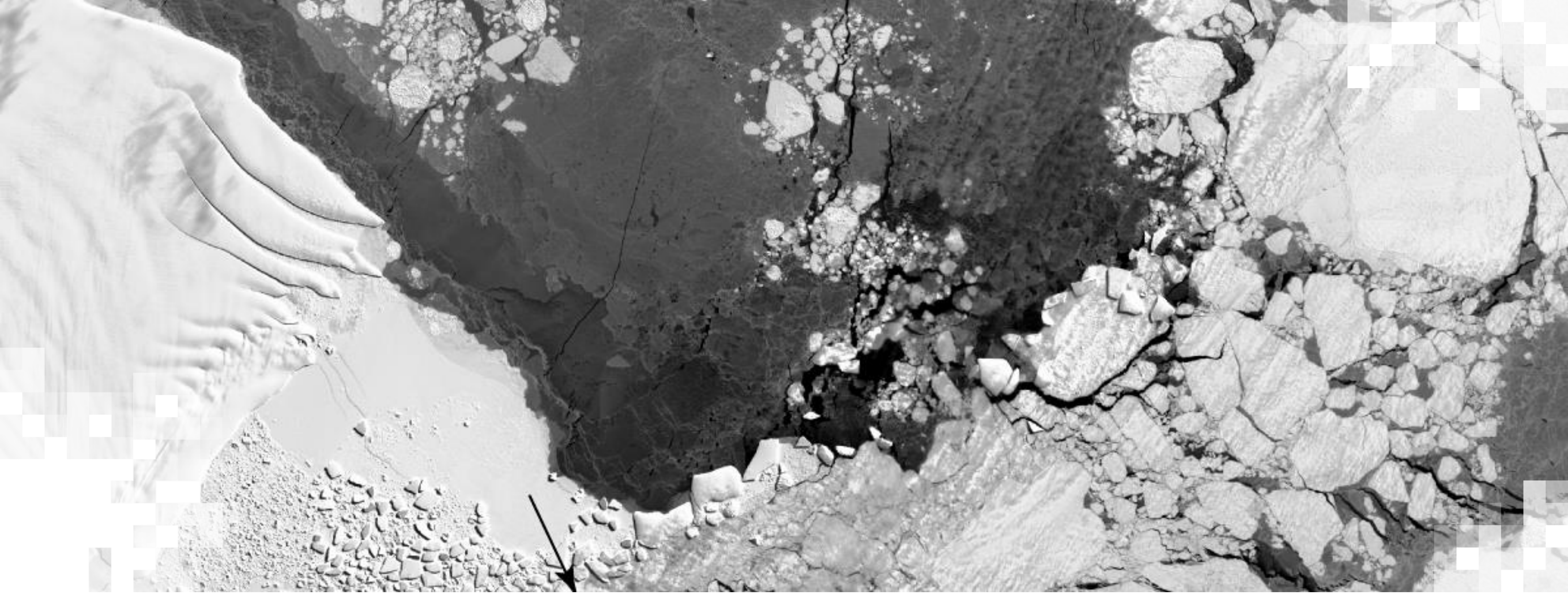
One-stop-shop for discovering, on-demand processing and downloading Synthetic Aperture Radar data



ASF Website

Information on SAR, available SAR data, processing Tutorials, and more



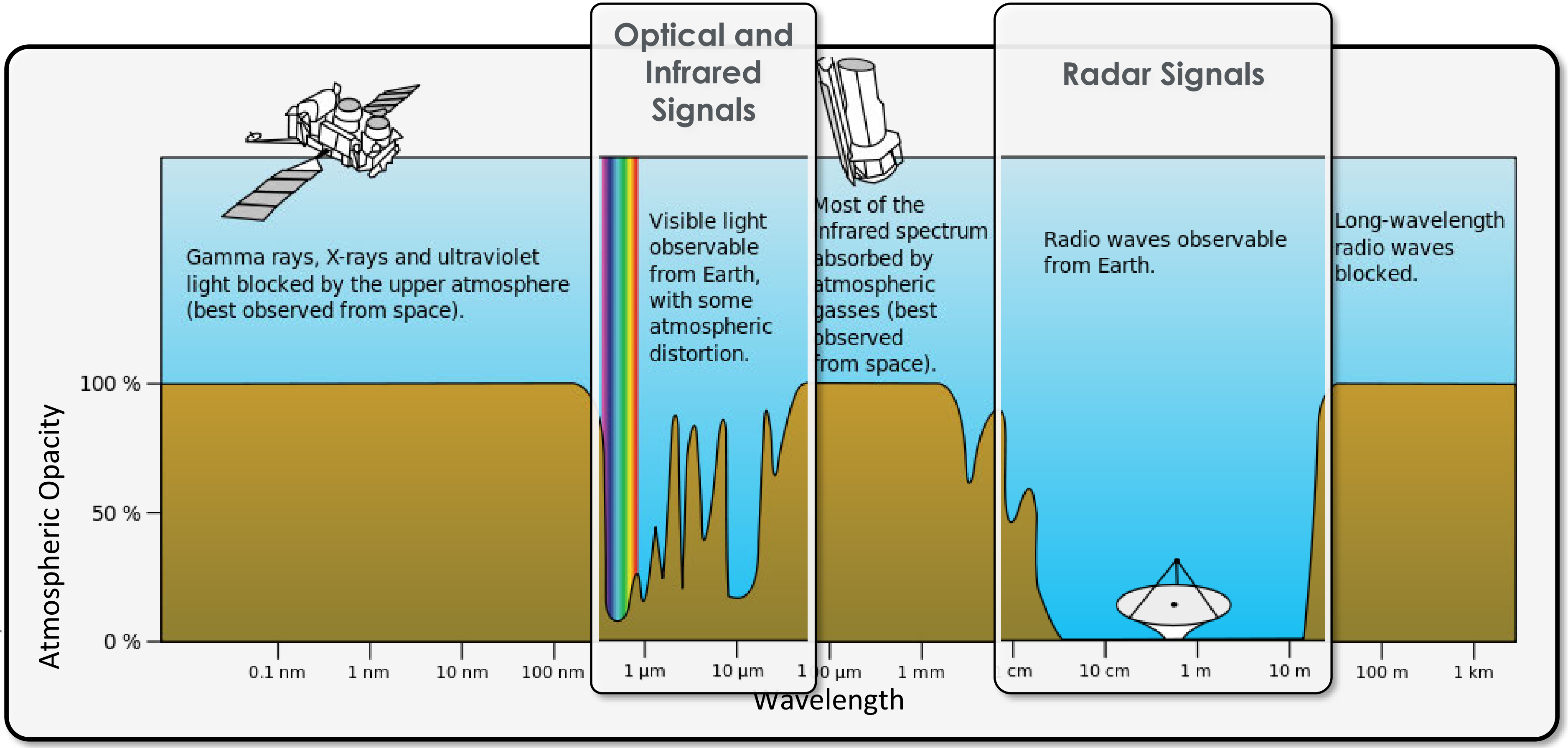


The Basics of SAR for Surface Water Mapping

Wavelength Discriminates Radar from Optical Data

- **Radar has excellent capabilities for routine global change monitoring**
  - **24/7 imaging capabilities:** due to weather & illumination independence
  - **Advanced change detection performance**: due to stable imaging conditions
  - **Complementary to optical sensors**: provides independent information

NASA Earth Observatory images by Robert Simmon, using Suomi NPP VIIRS data from Chris Elvidge (NOAA National Geophysical Data Center)



Weather Independence in Hazard Monitoring

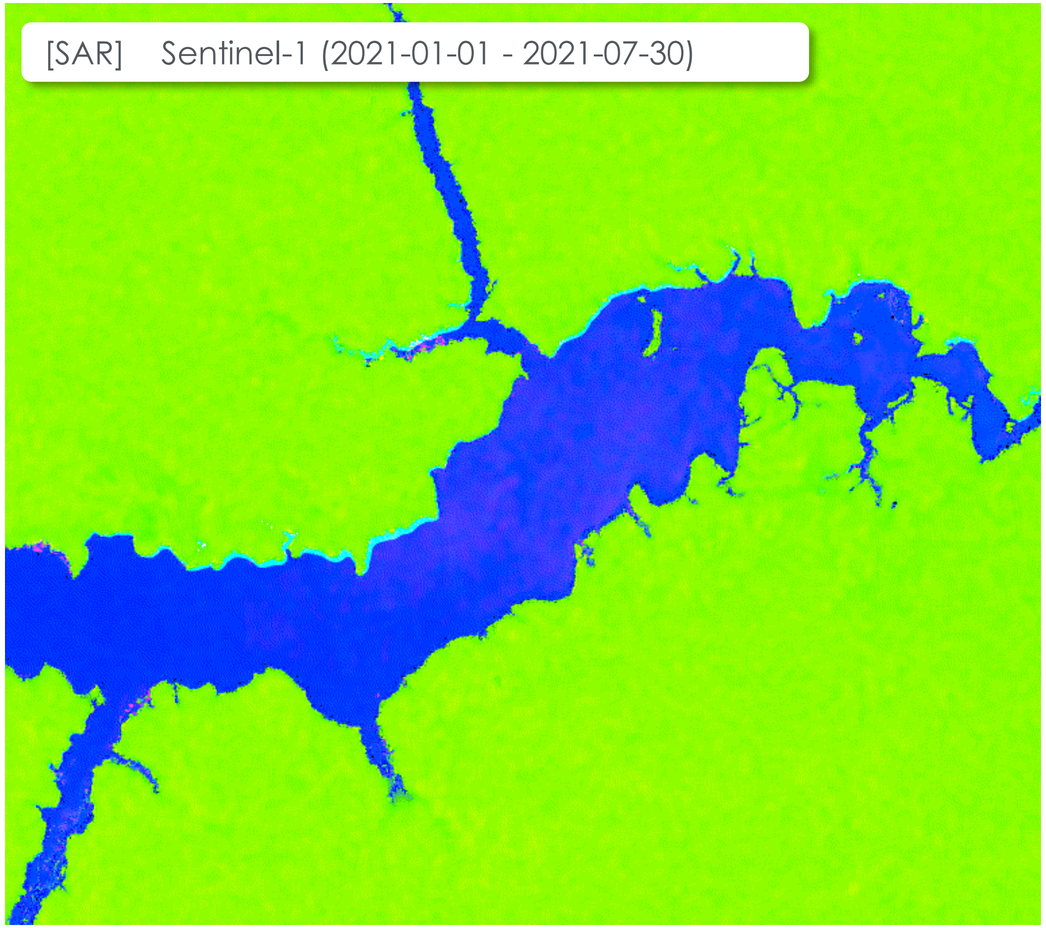
- Weather independence provides advantages, especially for weather-related events such as flooding and rain-triggered landslide activity.

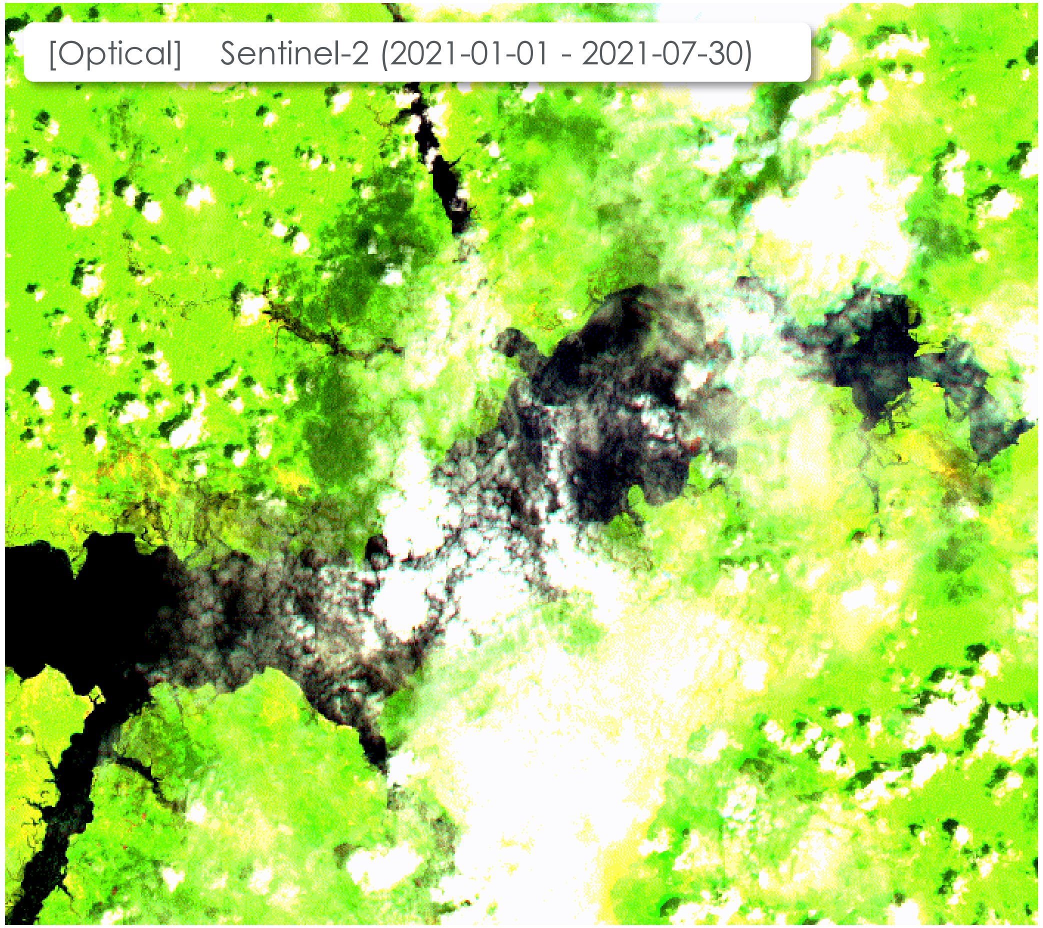
Animation of the Use of SAR During Flooding Events (Credit: DLR TerraSAR-X team)

Modern SAR Sensors provide regularly-sampled, high-resolution, and weather-independent Earth observation data from Space.

ESA Sentinel-1 SAR

Cloud-Free, Regularly-Observed SAR Images Allow Continuous Operational Surface Water Mapping





Seasonal Flooding in the Amazon Region

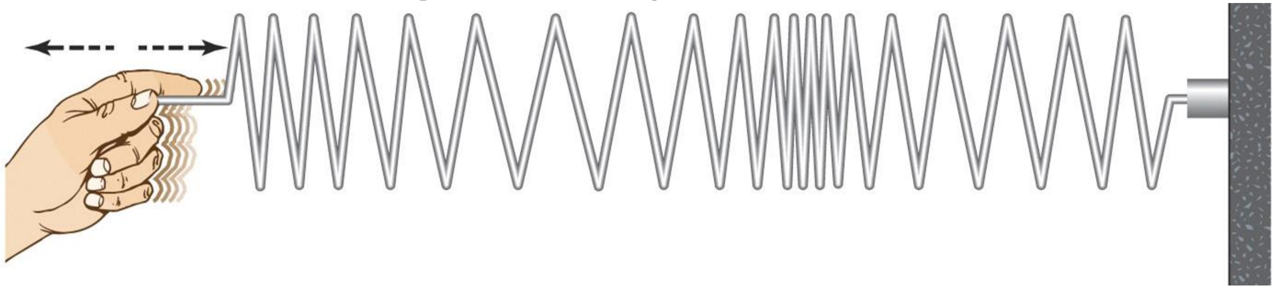
The Microwave Spectrum

(Approximate)

Band	Frequency f_0		Wavelength $\lambda = c/f_0$		Typical Application
Ka	27 – 40	GHz	1.1 – 0.8	cm	Rarely used for SAR
K	18 – 27	GHz	1.7 – 1.1	cm	
Ku	12 – 18	GHz	2.4 – 1.7	cm	
X	8 – 12	GHz	3.8 – 2.4	cm	**High-Resolution SAR** (urban monitoring; little penetration into vegetation cover→ can't see water under vegetation)
C	4 – 8	GHz	7.5 – 3.8	cm	**SAR Workhorse** (Sentinel-1; global mapping; improved vegetation penetration)
S	2 – 4	GHz	15 – 7.5	cm	**Increasing Use for SAR-Based Earth Observation**; NISAR will carry S-band
L	1 – 2	GHz	30 – 15	cm	**Medium-Resolution SAR** (NISAR; Geophysical monitoring; biomass and vegetation mapping; high penetration → can see water under vegetation)
P	0.3 – 1	GHz	100 – 30	cm	**Biomass Estimation**. ESA Biomass will be first P-band spaceborne SAR

Radar EM Signals are Transverse Oscillating Waves

Longitudinal Oscillating Waves (sound waves, waves on oceans)



Transverse Oscillating Waves (e.g., EM waves)

Transverse oscillating waves (like EM waves) have one additional degree of freedom:
The direction in which oscillation takes place, called **Polarization**.

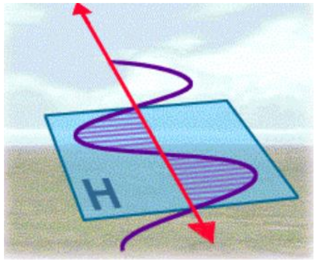
Polarization

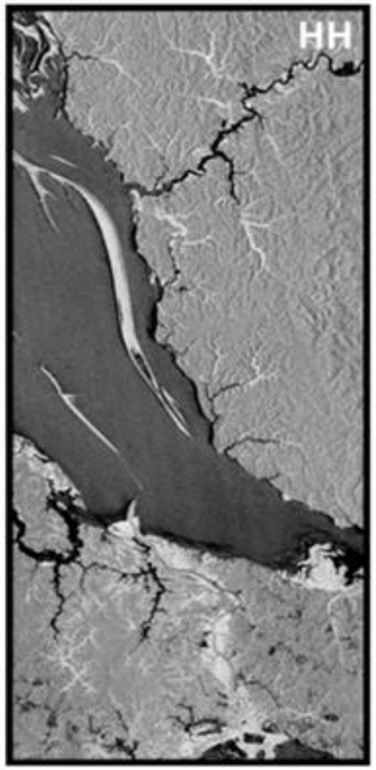
Polarization refers to the orientation of the electric field.

Most radars are designed to transmit microwave radiation & receive backscattered energy in either horizontal (H) or vertical (V) polarization.

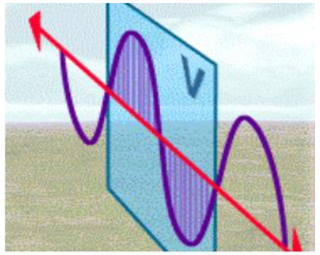
Co-Polarized

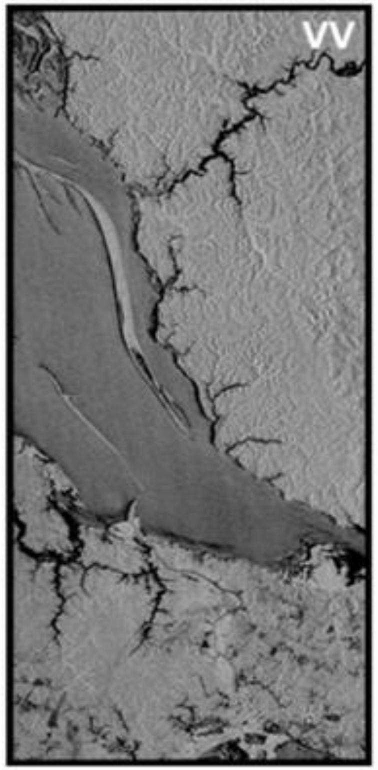
HH - Horizontal Transmit and Receive





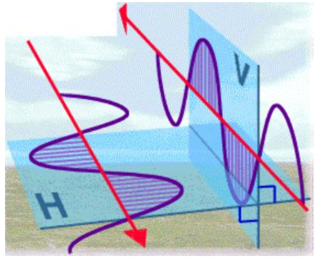
VV - Vertical Transmit and Receive

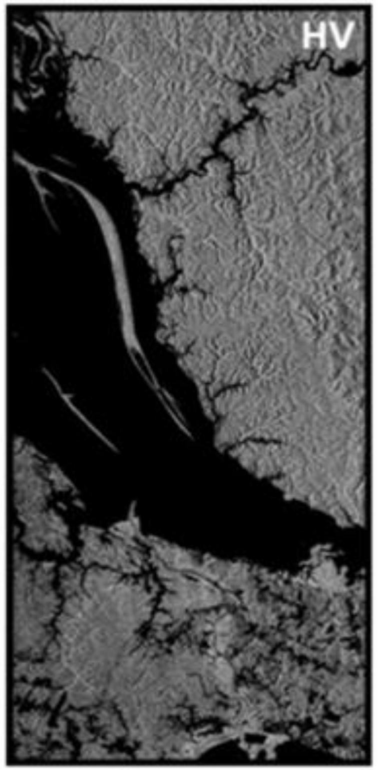




Cross-Polarized

HV - Horizontal Transmit and Vertical Receive





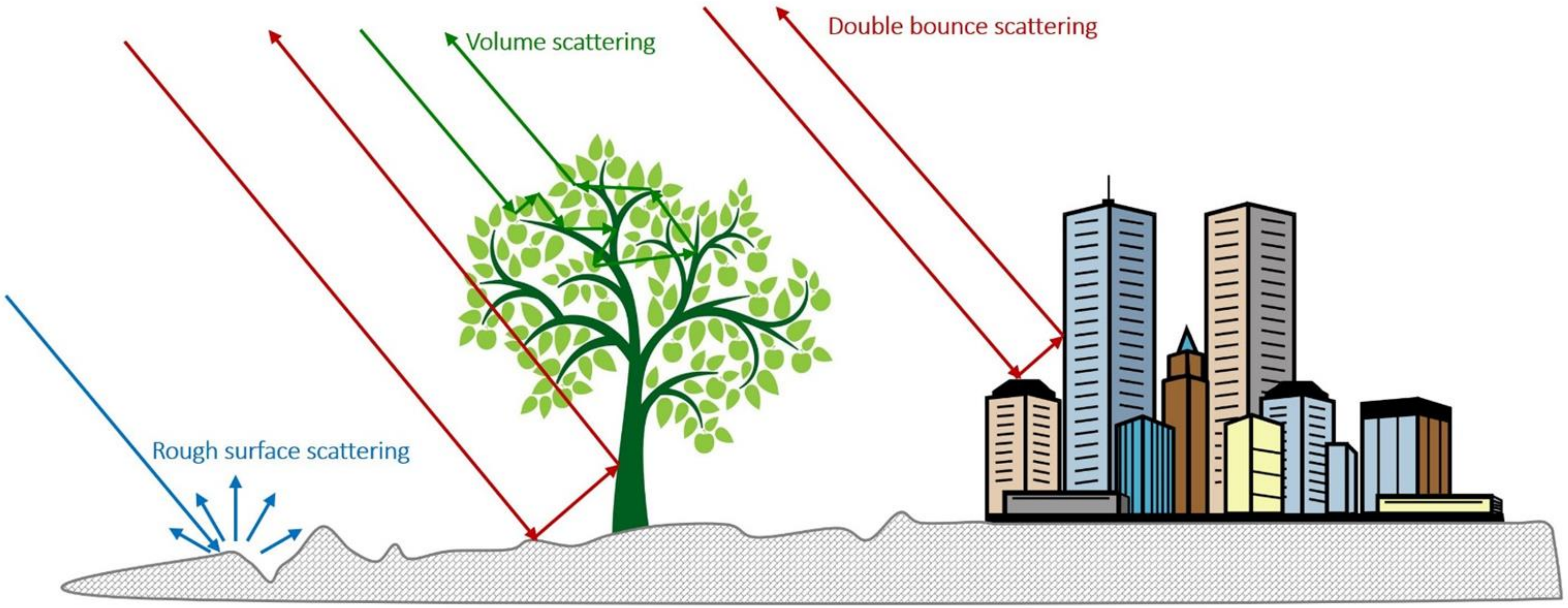
Images: PALSAR L-Band, Manaus, Brazil

[Modified After ARSAR & NASA ARSET]

Radar Backscatter from Objects on the Surface

At Radar wavelengths, scattering is physical (series of bounces on interfaces)

- **Three main scattering mechanisms dominate:**
  - **Scattering on (Rough) Surfaces:** Water, bare soils, roads; scattering dependent on surface roughness
  - **Double-Bounce Scattering:** Buildings, tree trunks; little wavelength dependence
  - **Volume Scattering:** Vegetation; backscatter dependent on sensor wavelength and biomass



Polarimetric Dependence of Scattering Principles

RELATIVE SCATTERING STRENGTH BY POLARIZATION:

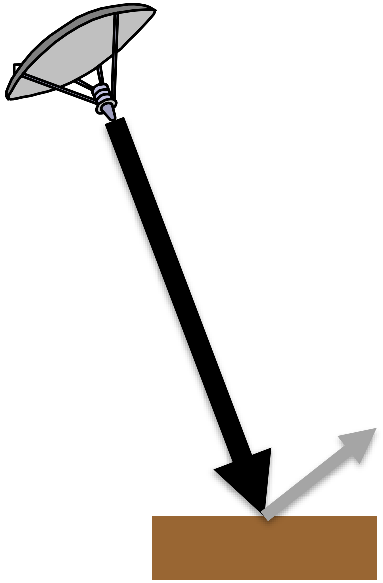
Rough Surface Scattering	$\|S_{VV}\| > \|S_{HH}\| > \|S_{HV}\|$ or $\|S_{VH}\|$
Double Bounce Scattering	$\|S_{HH}\| > \|S_{VV}\| > \|S_{HV}\|$ or $\|S_{VH}\|$
Volume Scattering	Main source of $\|S_{HV}\|$ and $\|S_{VH}\|$

Legend

Low Radar Brightness ($|S|$) — High Radar Brightness ($|S|$)

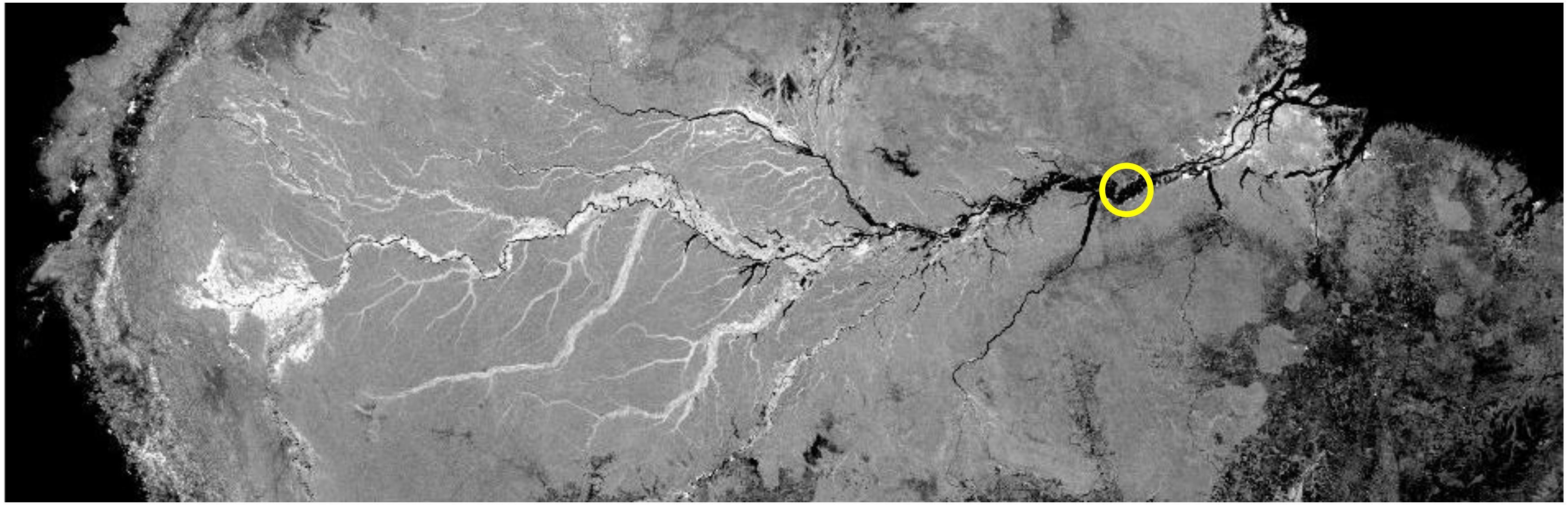
Examples of Radar Interaction

Smooth Surface Reflection (Specular Reflection)



Smooth, Level Surface
(Open Water, Road)

SMAP Radar Mosaic of the Amazon Basin
April 2015 (L-Band, HH, 3 km)



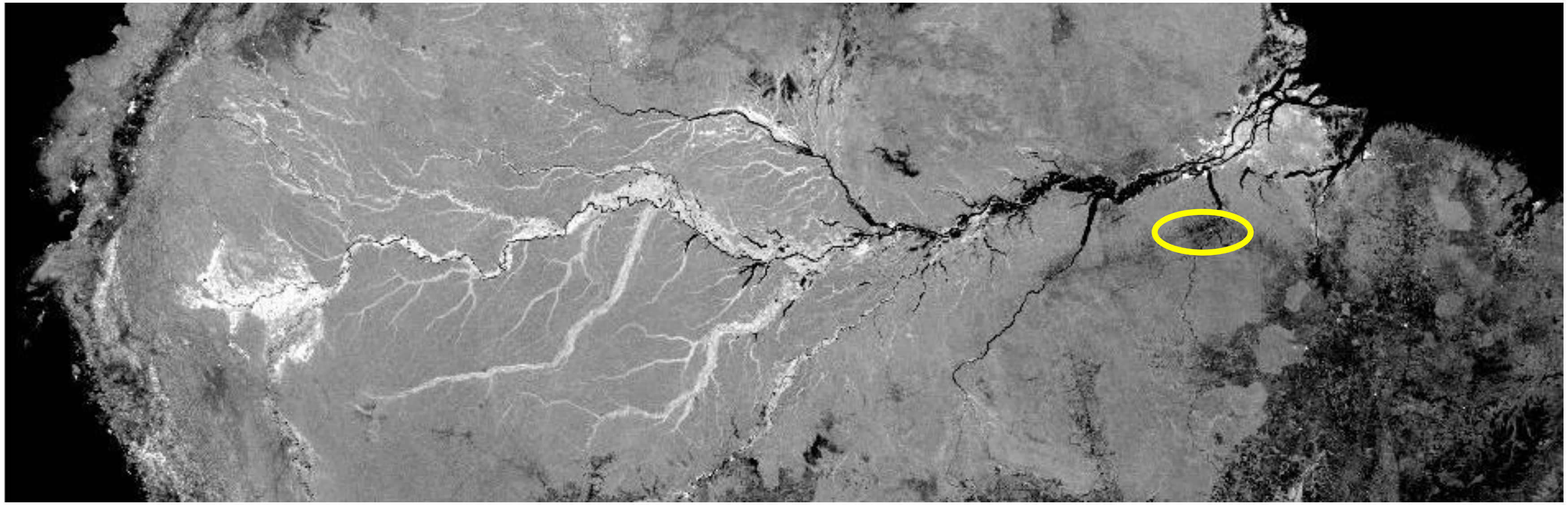
Pixel Color

Examples of Radar Interaction

Rough Surface Scattering

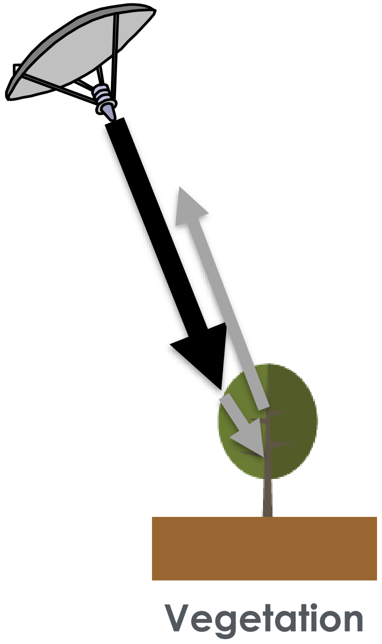
Rough, Bare Surface
(Deforested Areas, Tilled Agricultural Fields)

SMAP Radar Mosaic of the Amazon Basin
April 2015 (L-Band, HH, 3 km)

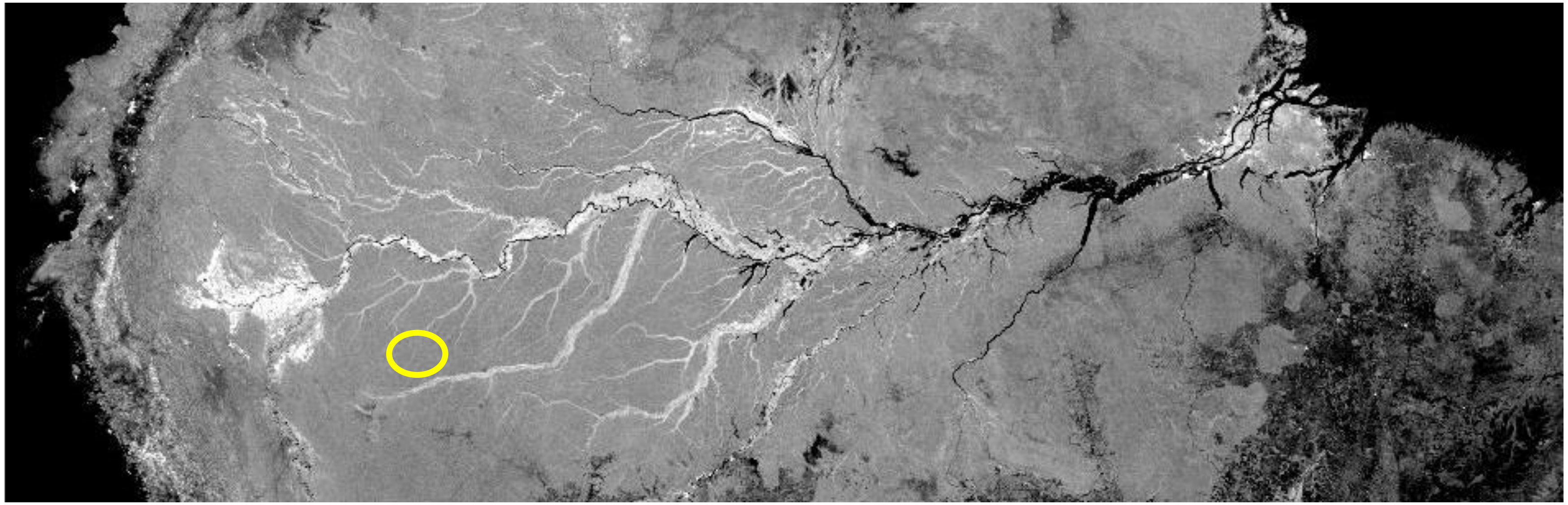


Pixel Color

Examples of Radar Interaction
Volume Scattering by Vegetation

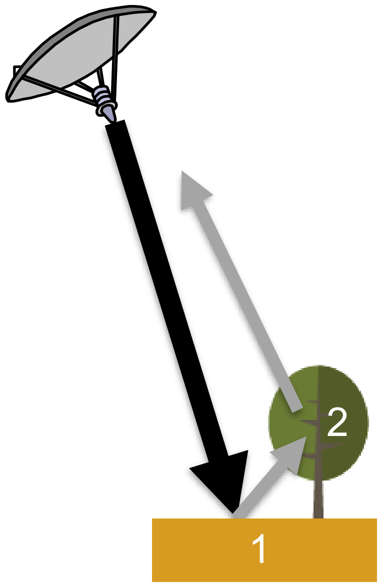


SMAP Radar Mosaic of the Amazon Basin
April 2015 (L-Band, HH, 3 km)



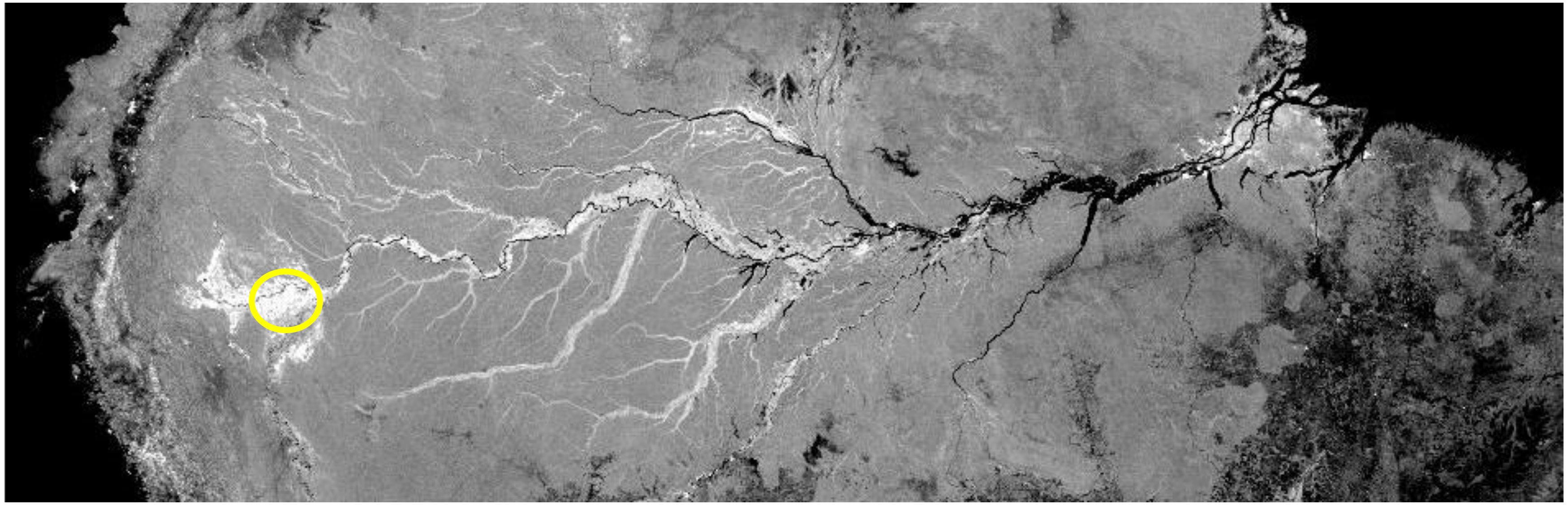
Pixel Color

Examples of Radar Interaction
Double Bounce Scattering



Inundated Vegetation

SMAP Radar Mosaic of the Amazon Basin
April 2015 (L-Band, HH, 3 km)



Pixel Color

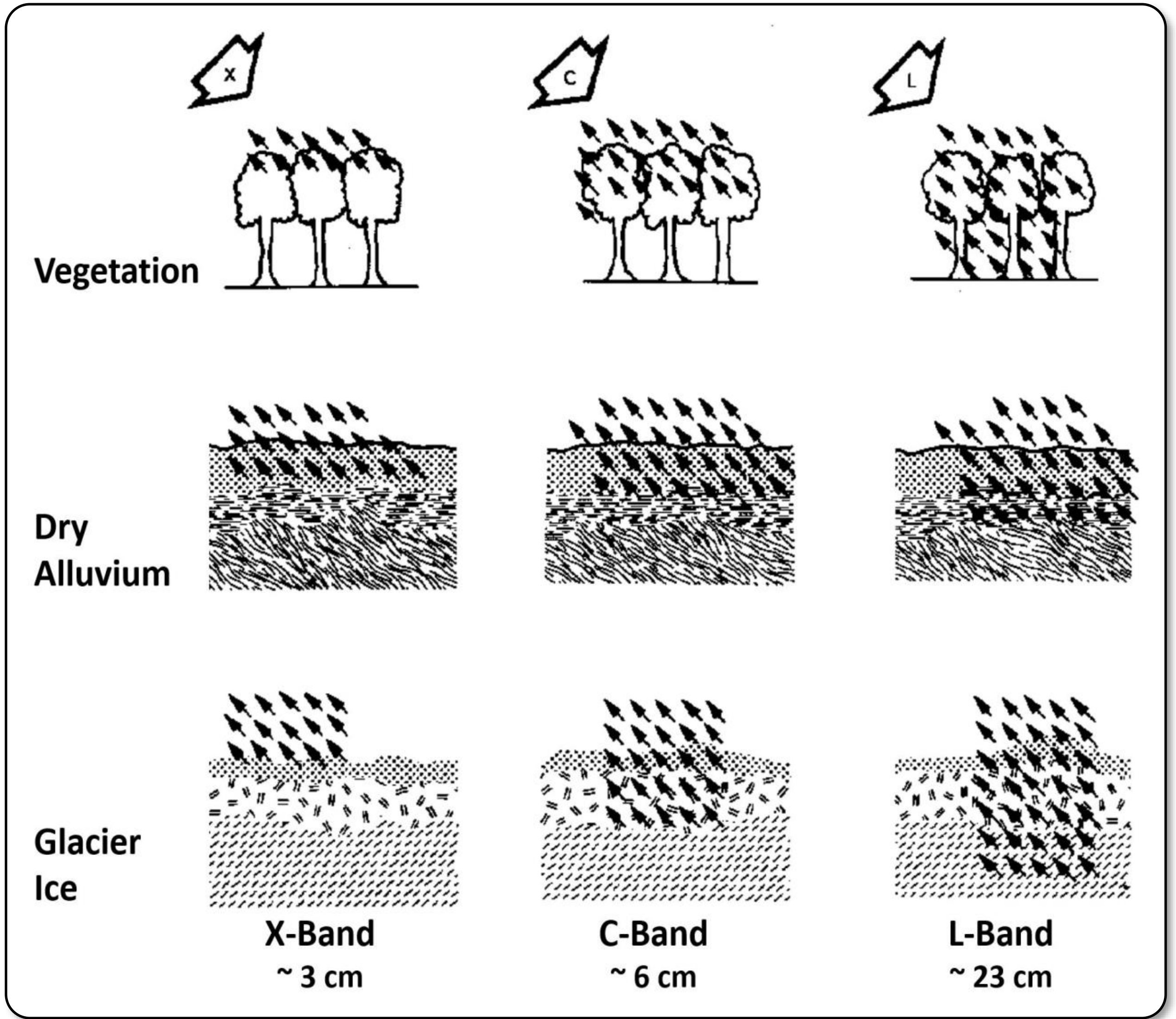
Influence of Wavelength on Signal Penetration

Penetration into vegetation and soils increases with sensor wavelength.

L-Band Penetration **>** C-band **>** X-band

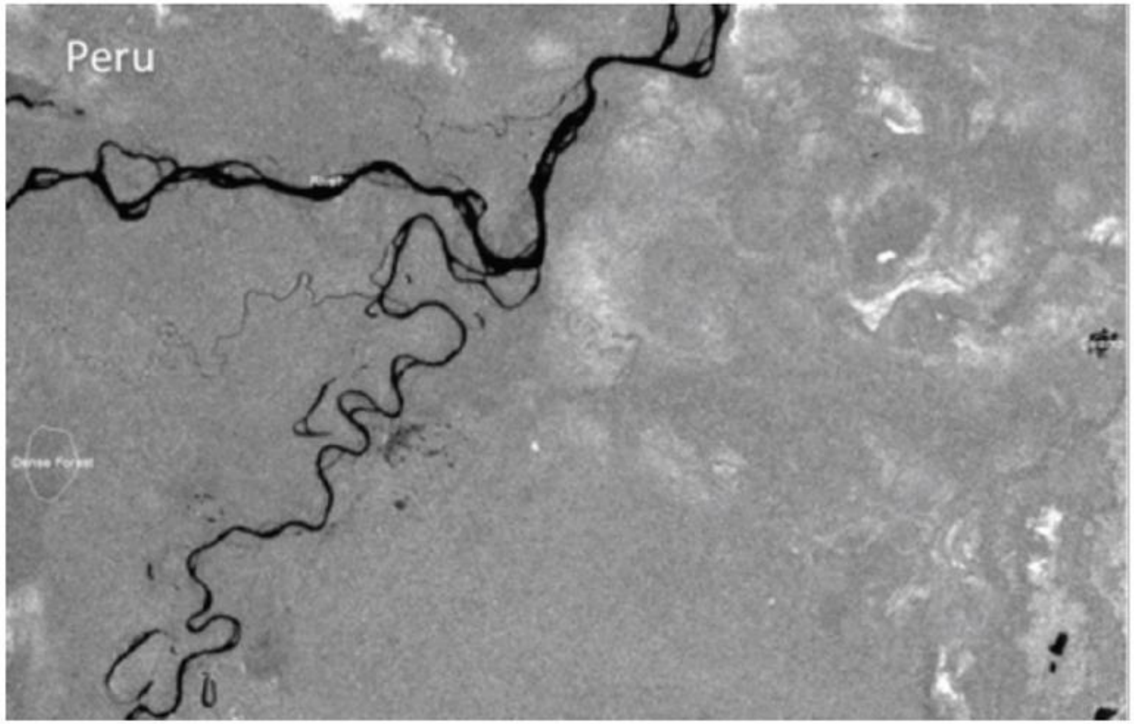
For Flood Monitoring:

– X-band SAR mostly scatters at the tops of tree canopies.
– C- and L-band signals penetrate increasingly.
– Longer wavelength → **improved mapping of inundation under forest canopies**.

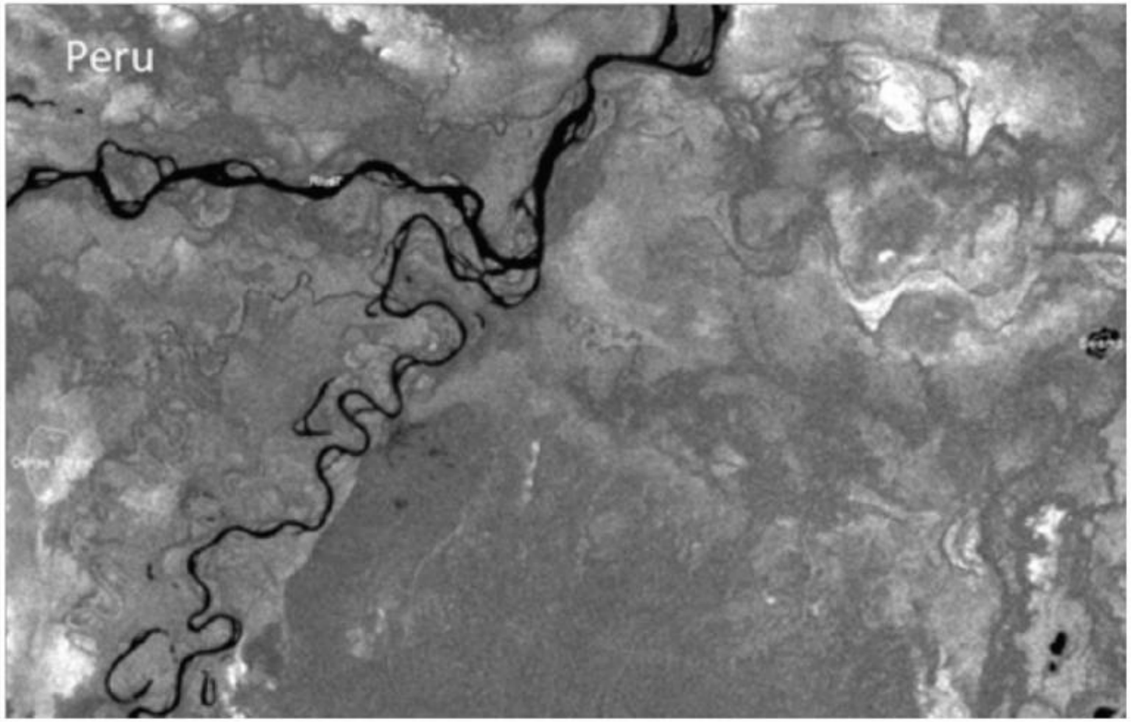


Inundation Under Vegetation at L-Band Frequencies

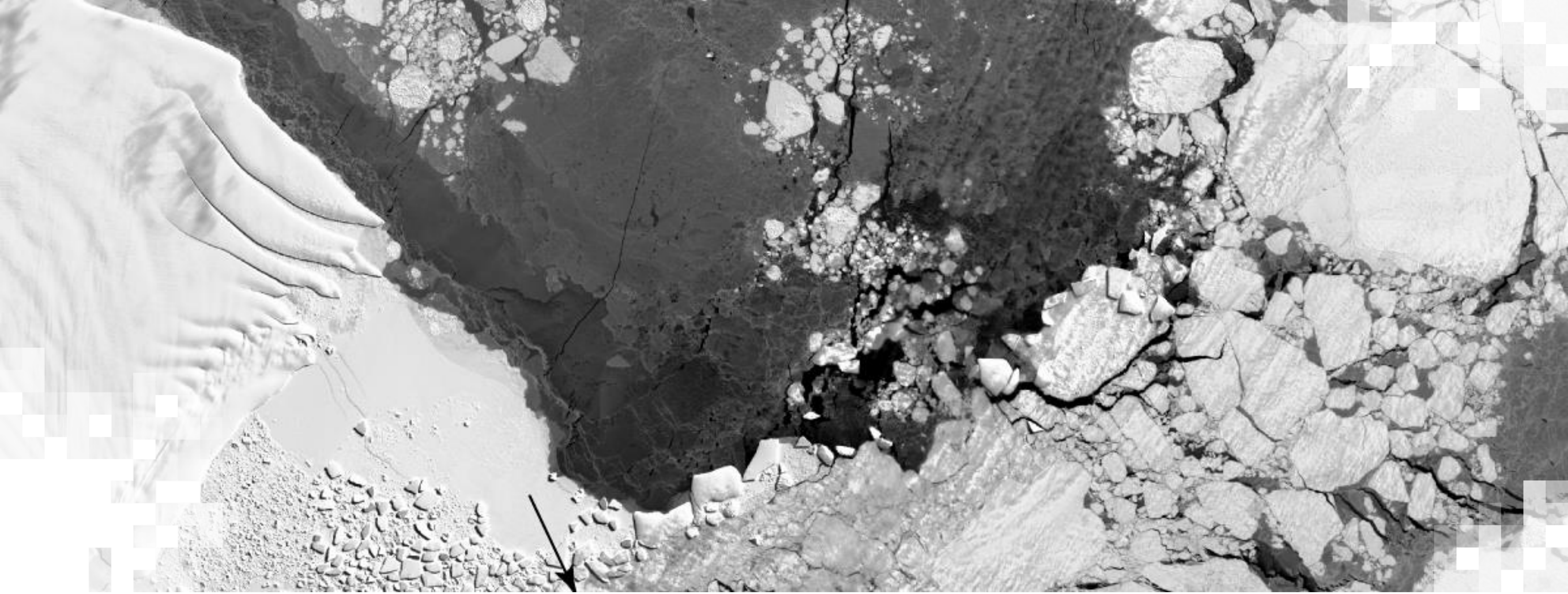
- **Increased Double-Bounce from Under-Canopy Flooding (L-HH ALOS-1):**
  - Note the brightening of the forests during inundation.



Low-Water Season



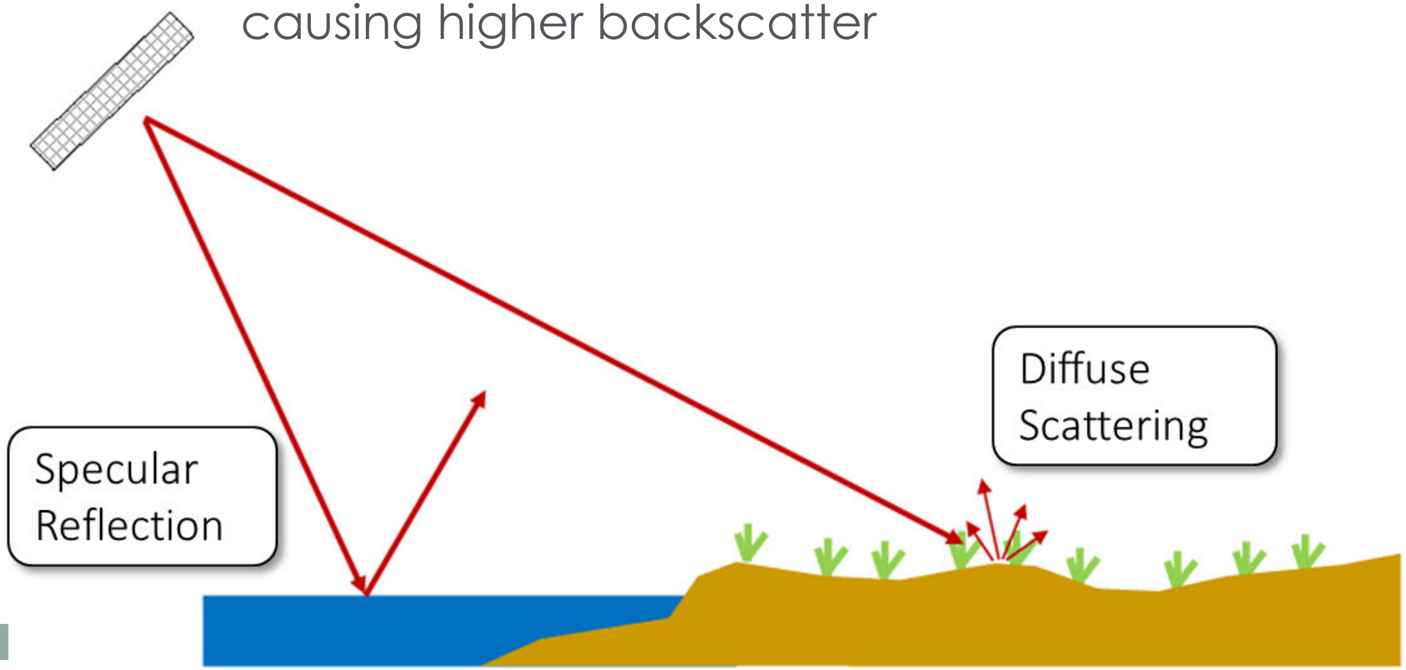
High-Water Season



Surface Water Signatures in SAR Images

Surface Water Signatures in SAR Amplitude Images

- **Mapping of water surfaces based on different radar signatures of water and land**
  - Calm water surfaces appear smooth and cause specular reflection leading to low backscatter
  - Surrounding land surface appears much rougher, causing higher backscatter



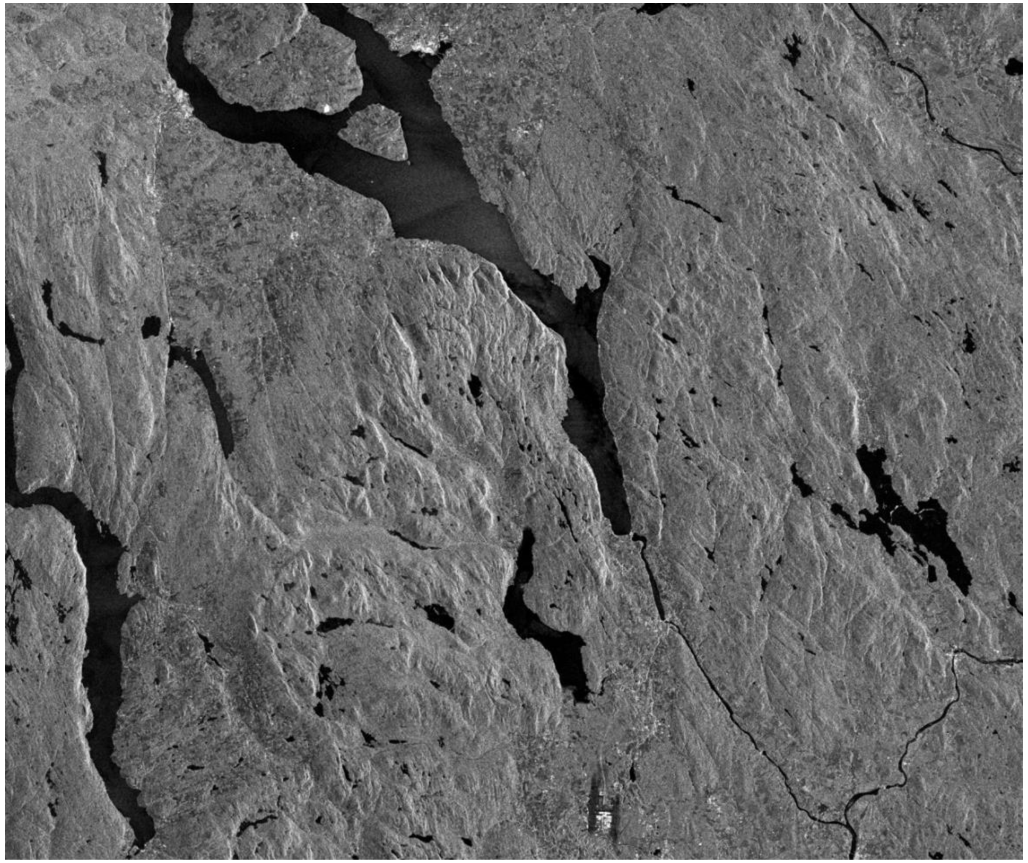
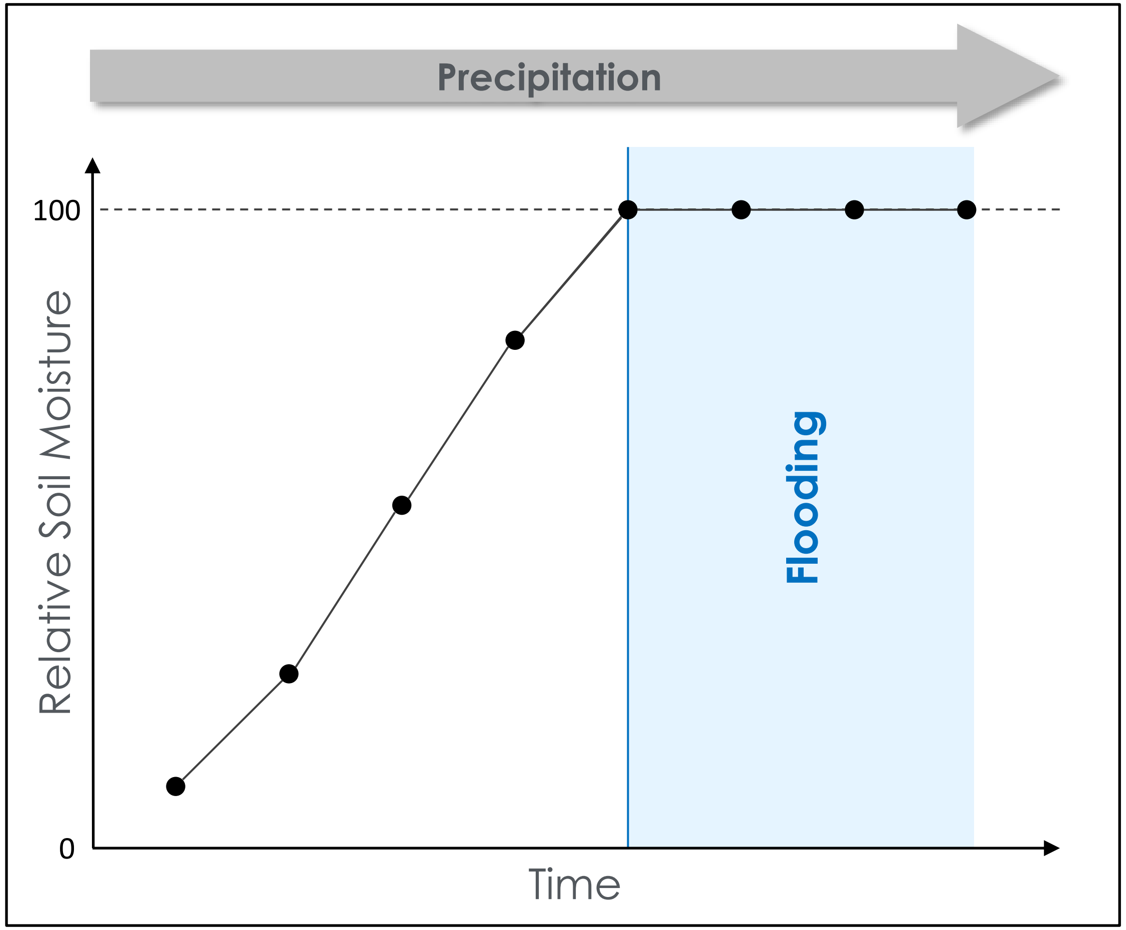


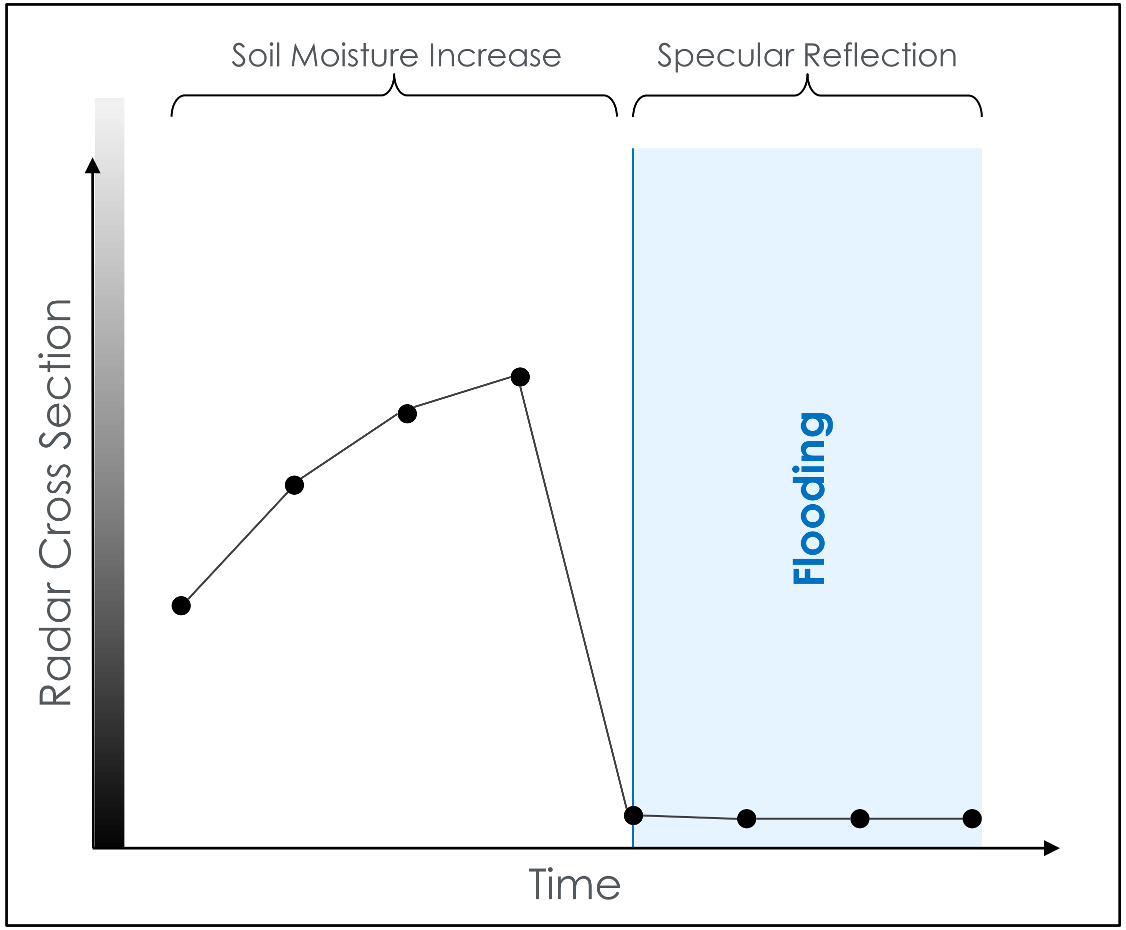
Fig.: Lake Mjosa, Norway, observed by ENVISAT ASAR Image Mode, 12 Dec 2003 (©ESA Multimedia Gallery)

Surface Water Signatures in SAR Amplitude Images

1. Open Lands – Areas with Low Vegetation Cover

Relative SAR Response Over Open Lands as Precipitation Increases:

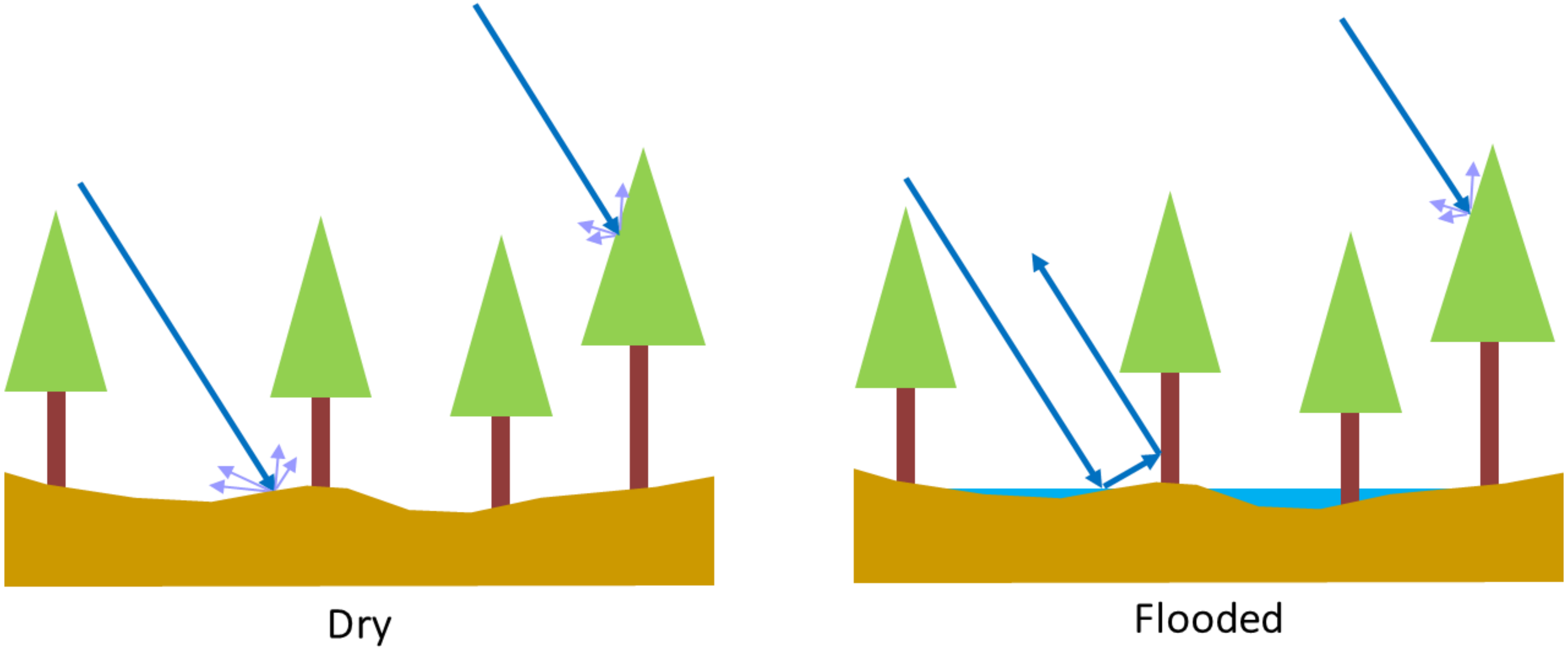




Surface Water Signatures in SAR Amplitude Images

2. Flooding under Vegetation Canopies

- **Mapping Inundation under Vegetation Canopies:**



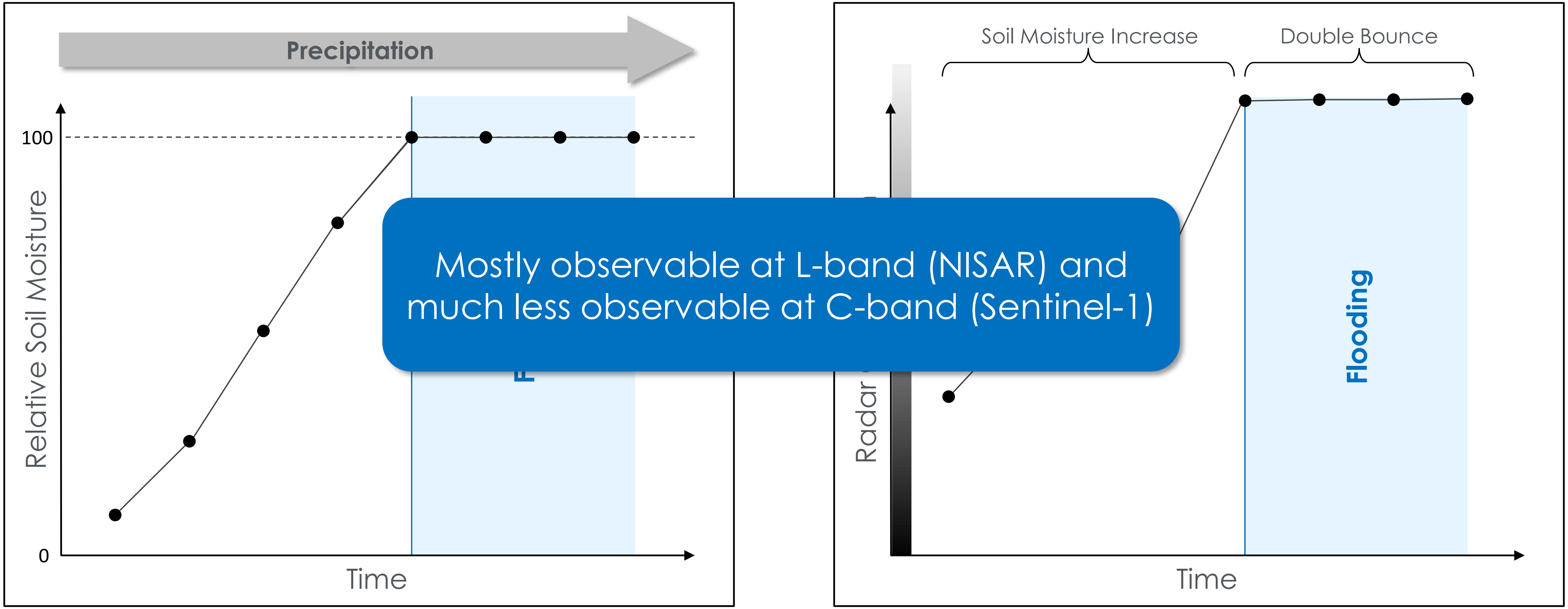
Enhanced return if tree cover underlain by water (double bounce effect – smooth water surface – vertical vegetation structures)

Fig.: Inundation effects on radar backscatter for forest stands (after Bourgeau-Chavez et al., 2009)

Surface Water Signatures in SAR Amplitude Images

2. Flooding under Vegetation Canopies

Relative SAR Response in Vegetated Canopies as Precipitation Increases:



Mostly observable at L-band (NISAR) and much less observable at C-band (Sentinel-1)

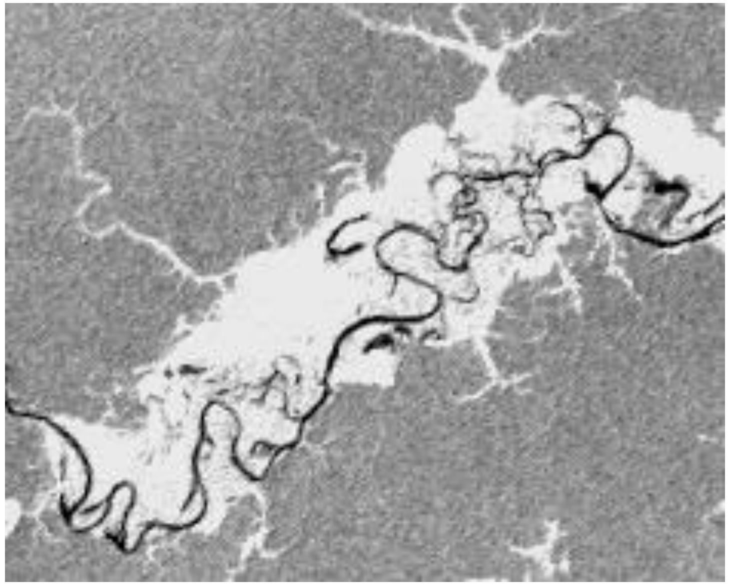
Surface Water Signatures in SAR Amplitude Images

2. Flooding under Vegetation Canopies – Example

Varzea Dry Season

Varzea Wet Season

JERS-1 Dry Season



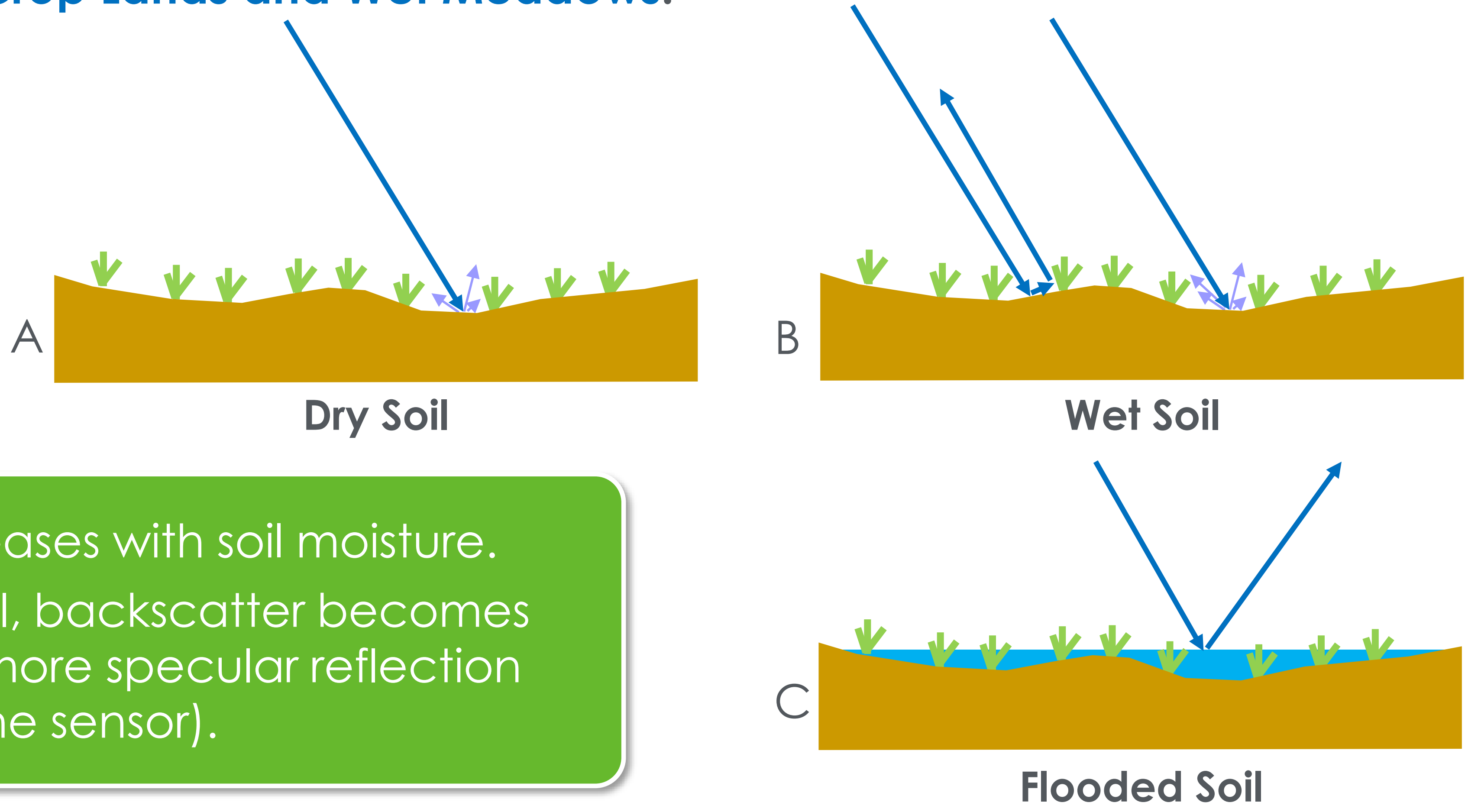
JERS-1 Dry Season

L-Band Example

Surface Water Signatures in SAR Amplitude Images

3. Flooding in Crop Lands

- **Mapping Inundation in Crop Lands and Wet Meadows:**



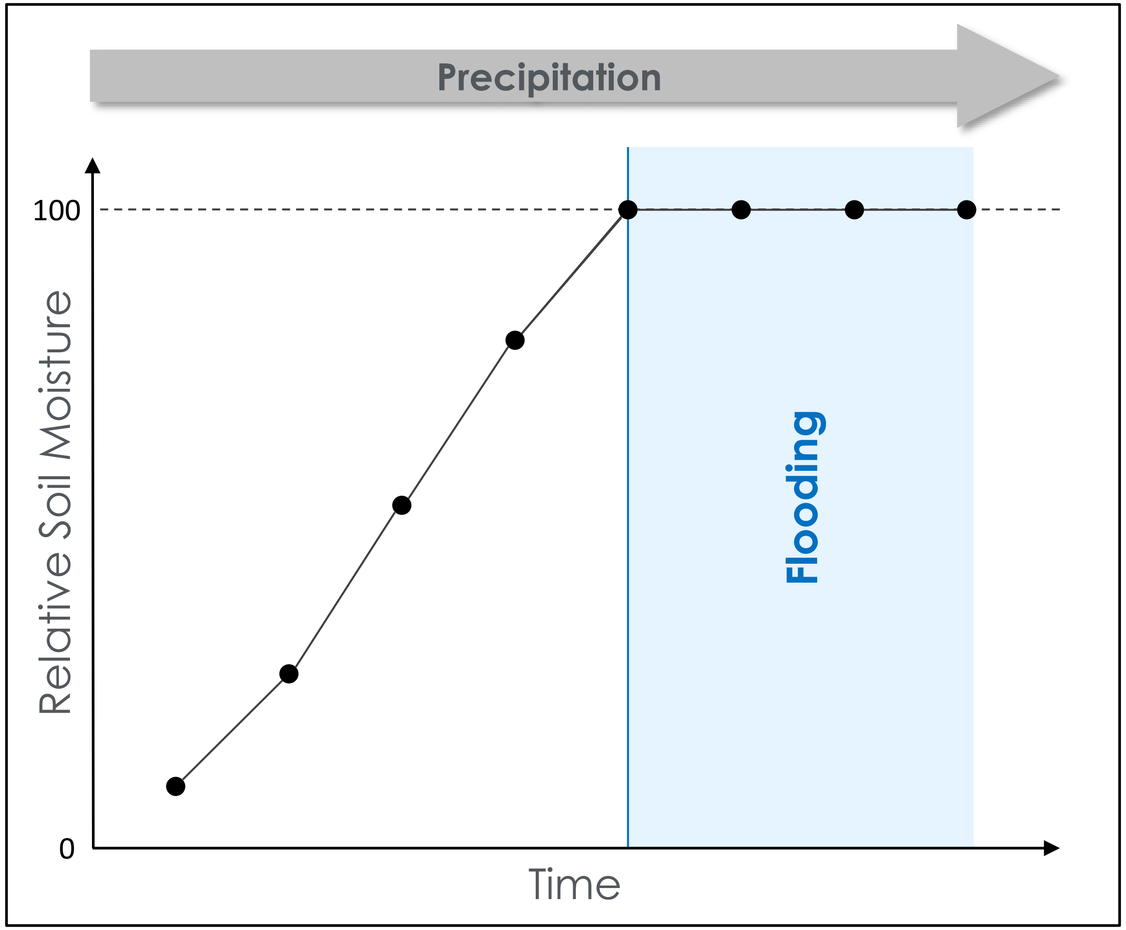
- **A to B**: Backscatter increases with soil moisture.
- **C**: Increasing water level, backscatter becomes weaker with more and more specular reflection (scattering away from the sensor).

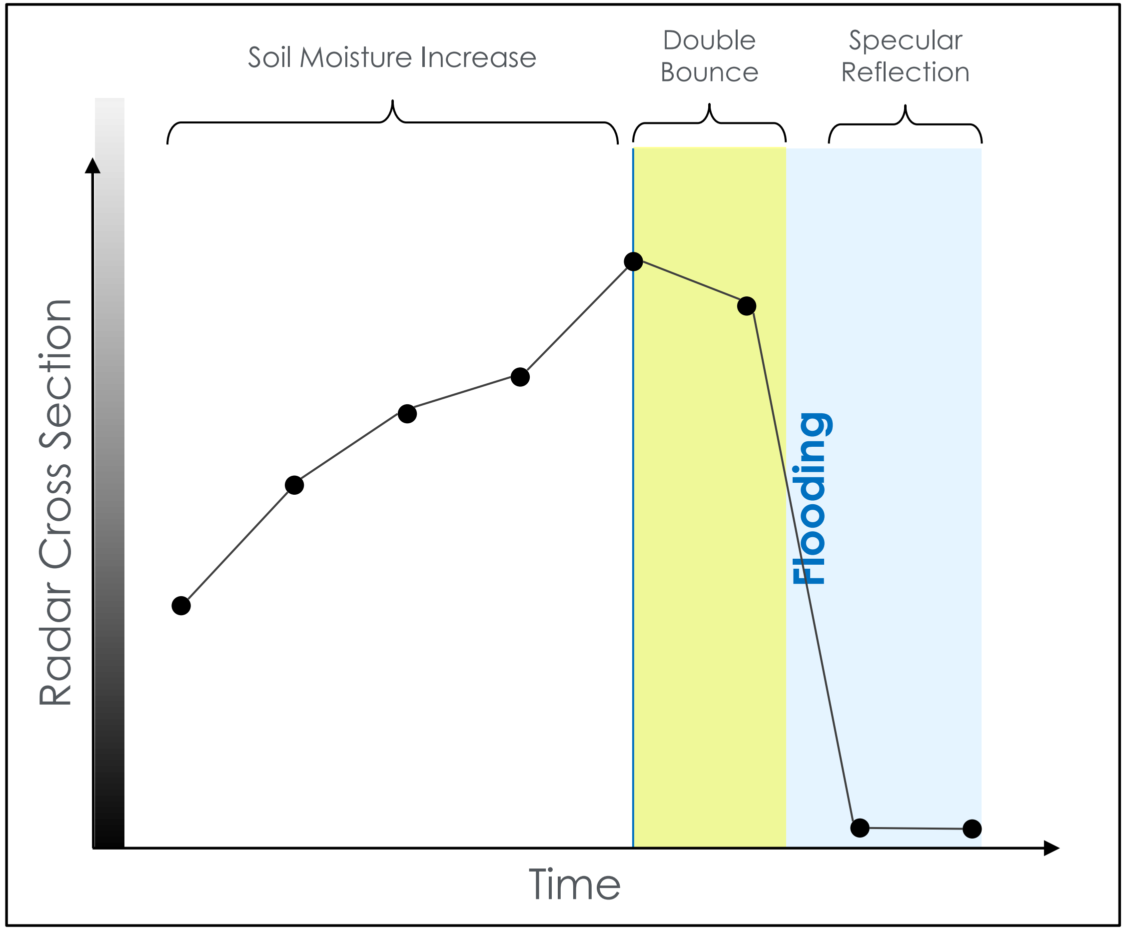
Fig.: Inundation effects on radar backscatter for wet meadows (after Bourgeau-Chavez et al., 2009)

Surface Water Signatures in SAR Amplitude Images

3. Flooding in Crop Lands

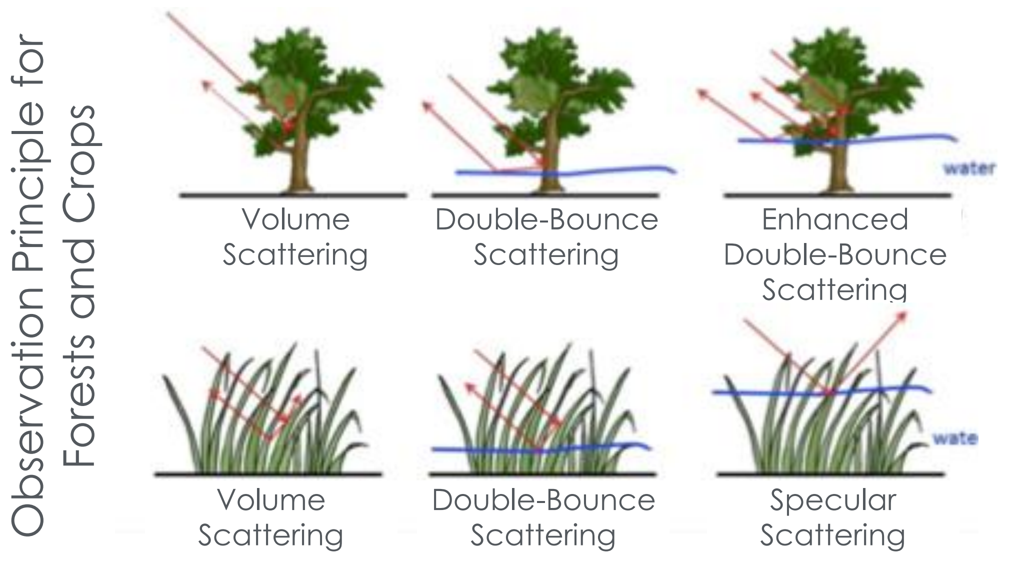
- **Relative SAR response in crop lands as precipitation increases:**





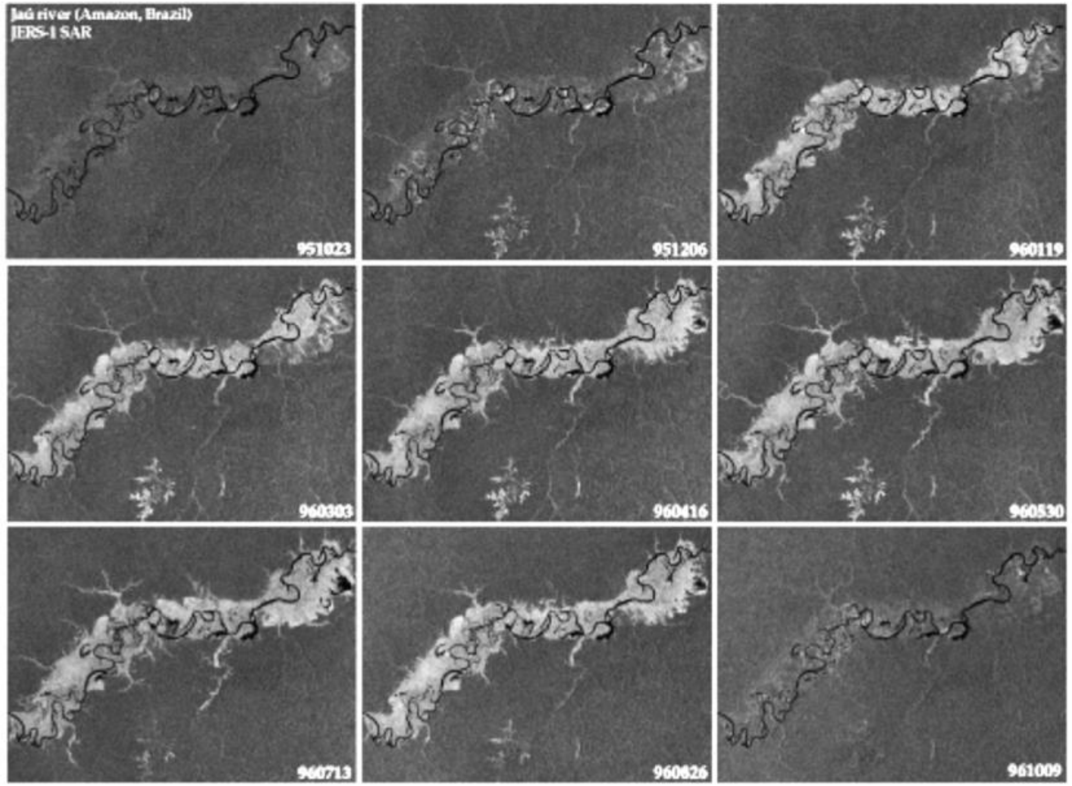
Vegetation Inundation Mapping using SAR

SAR observations (especially at L-band) are established as a reliable tool for mapping vegetation inundation.



- C-band sensors show limited performance in densely vegetated areas.
- Future sensors such as NISAR will help monitoring water under trees and wetland hydrology.

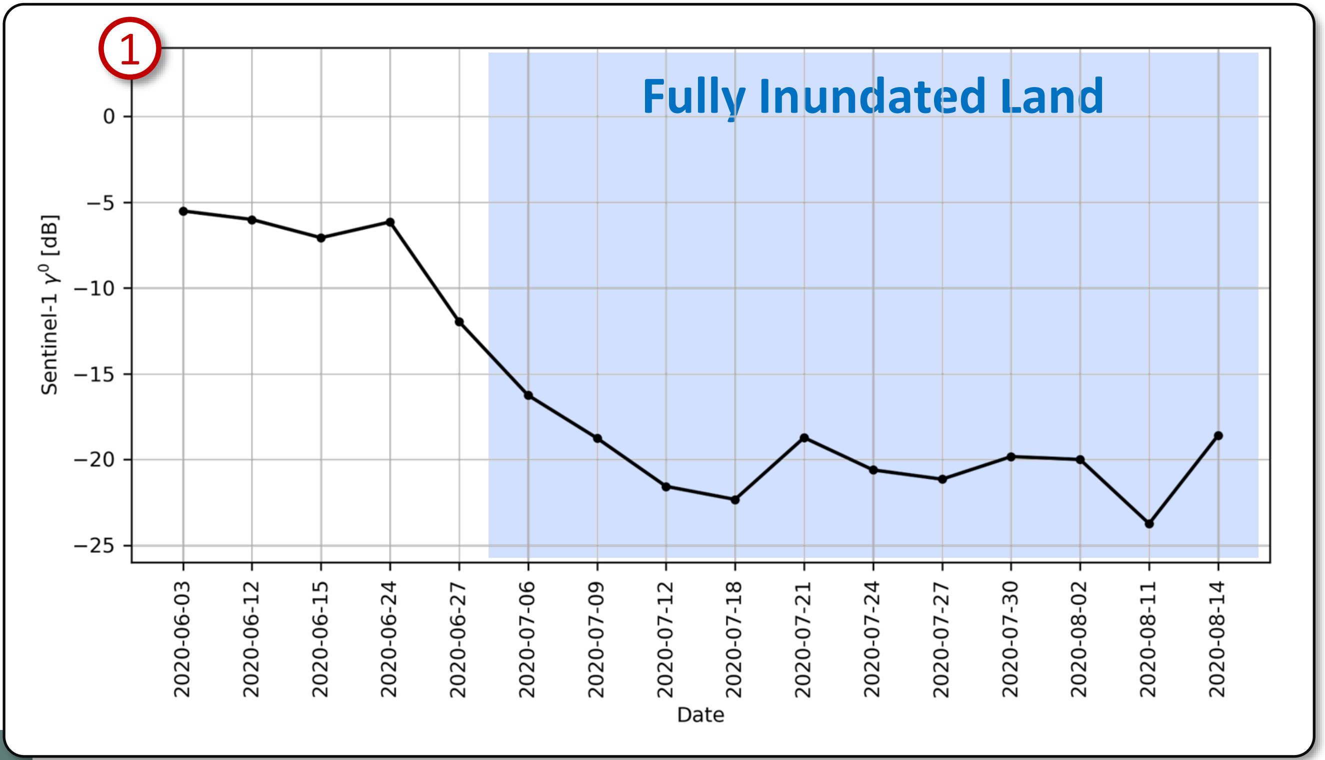
JERS-1 L-Band SAR Data Showing Inundation Dynamics (Jau River, Brazil)



Rosenqvist et al, 1998.

Vegetation Signature Examples

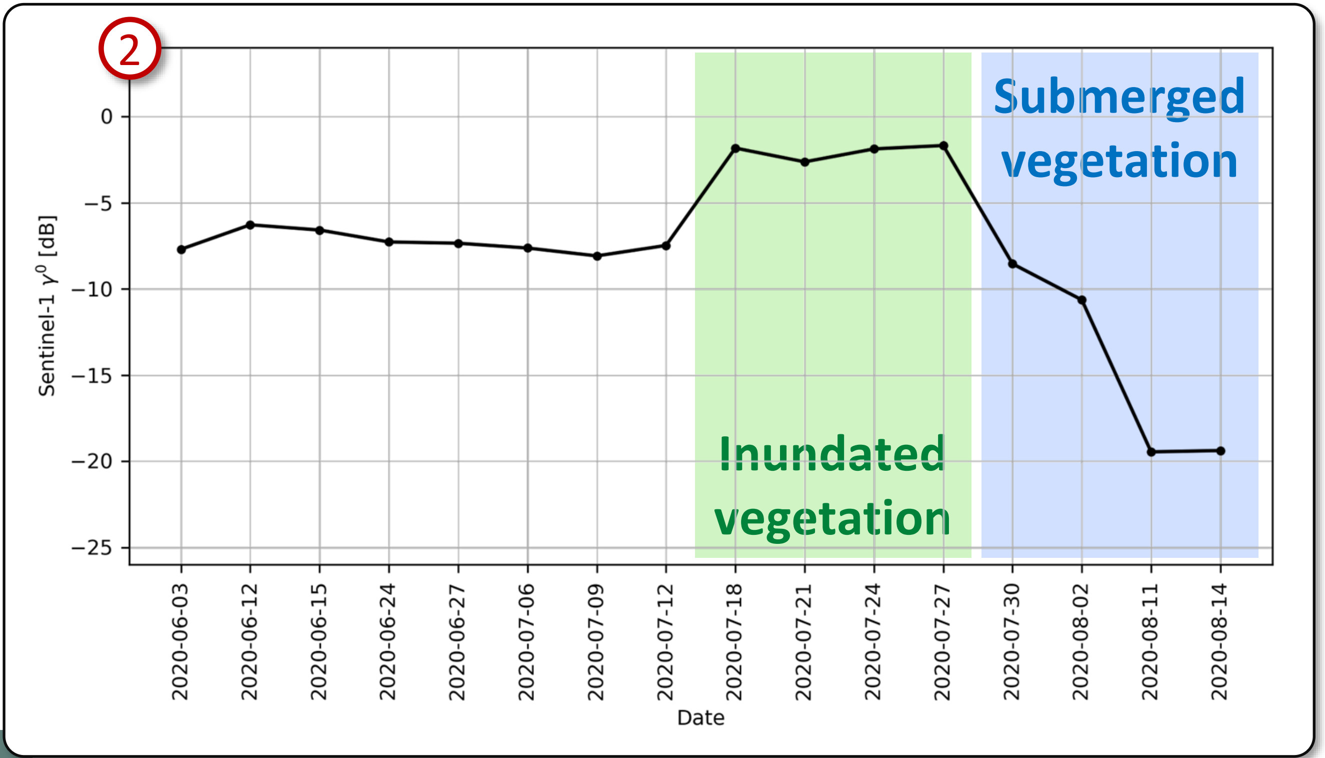
2020 South Asia Monsoon Floods – West Bengal Region, India



2020-06-03

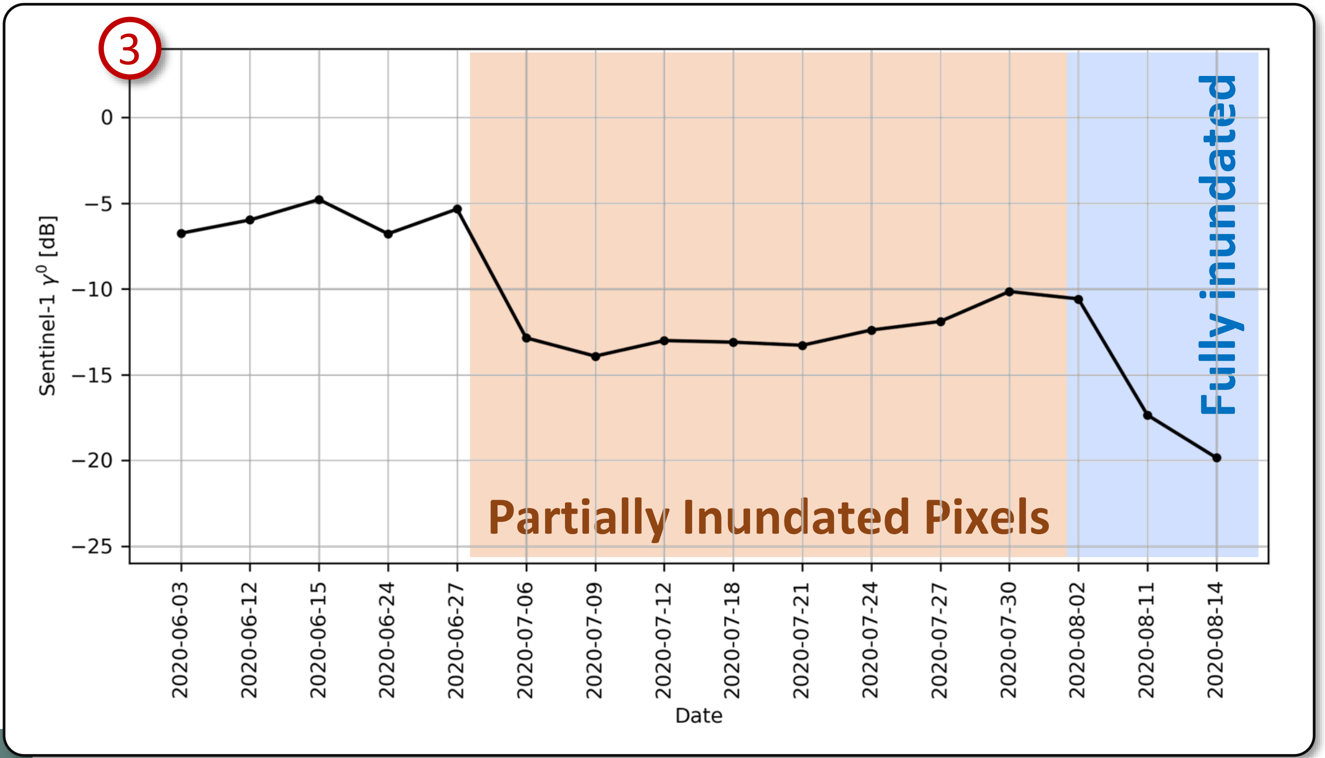
Vegetation Signature Examples

2020 South Asia Monsoon Floods – West Bengal Region, India



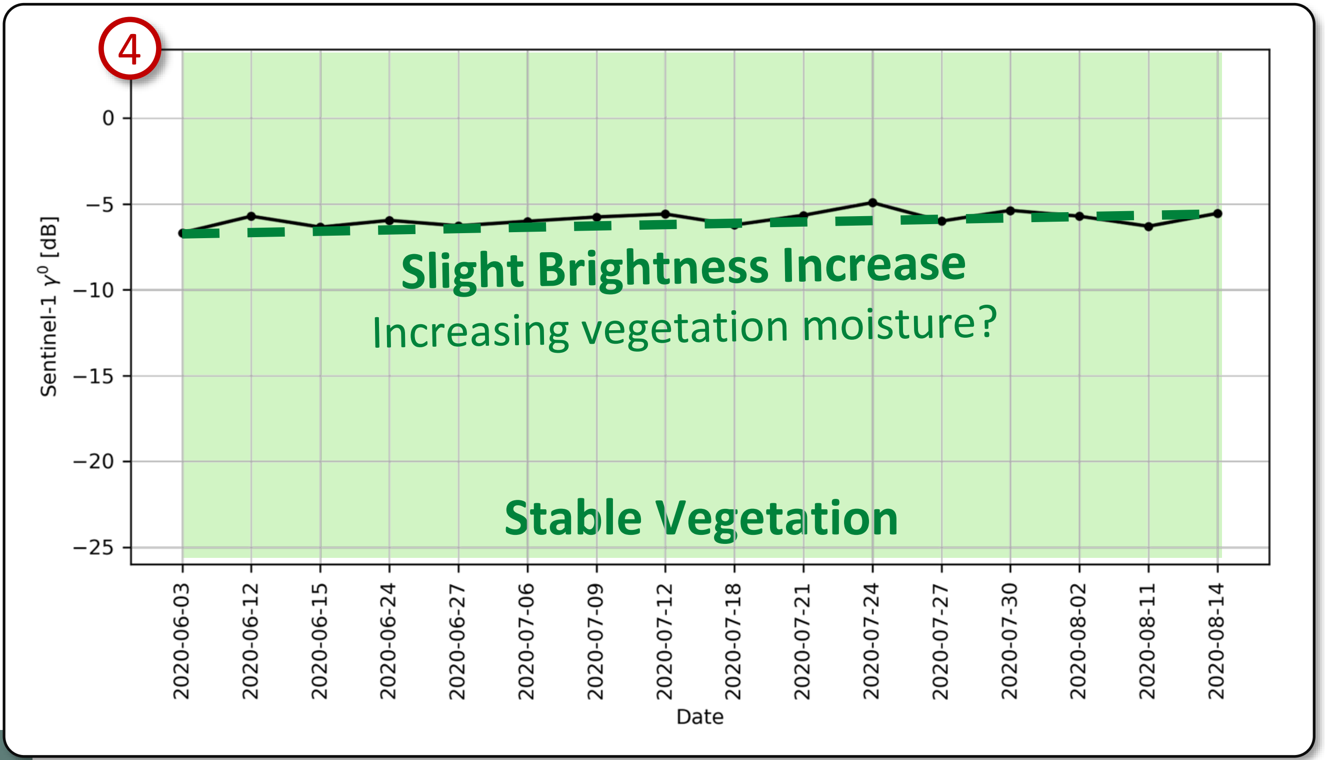
Vegetation Signature Examples

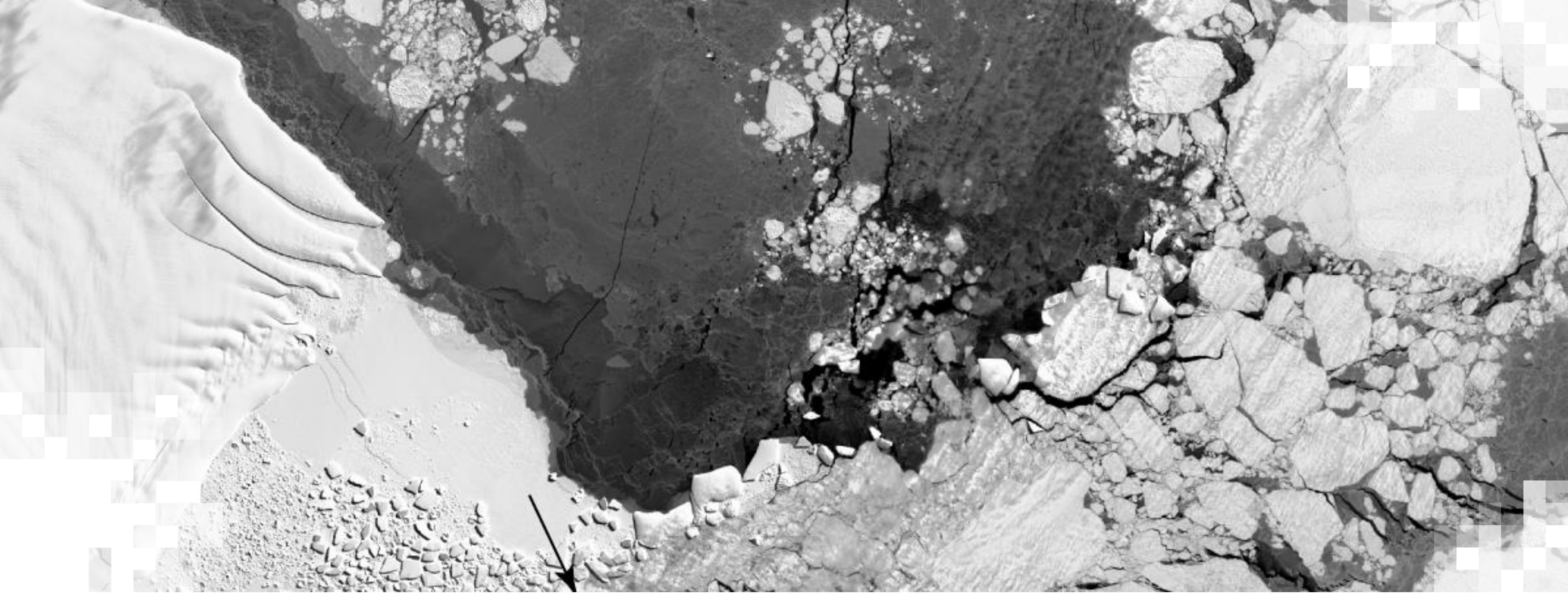
2020 South Asia Monsoon Floods – West Bengal Region, India



Vegetation Signature Examples

2020 South Asia Monsoon Floods – West Bengal Region, India

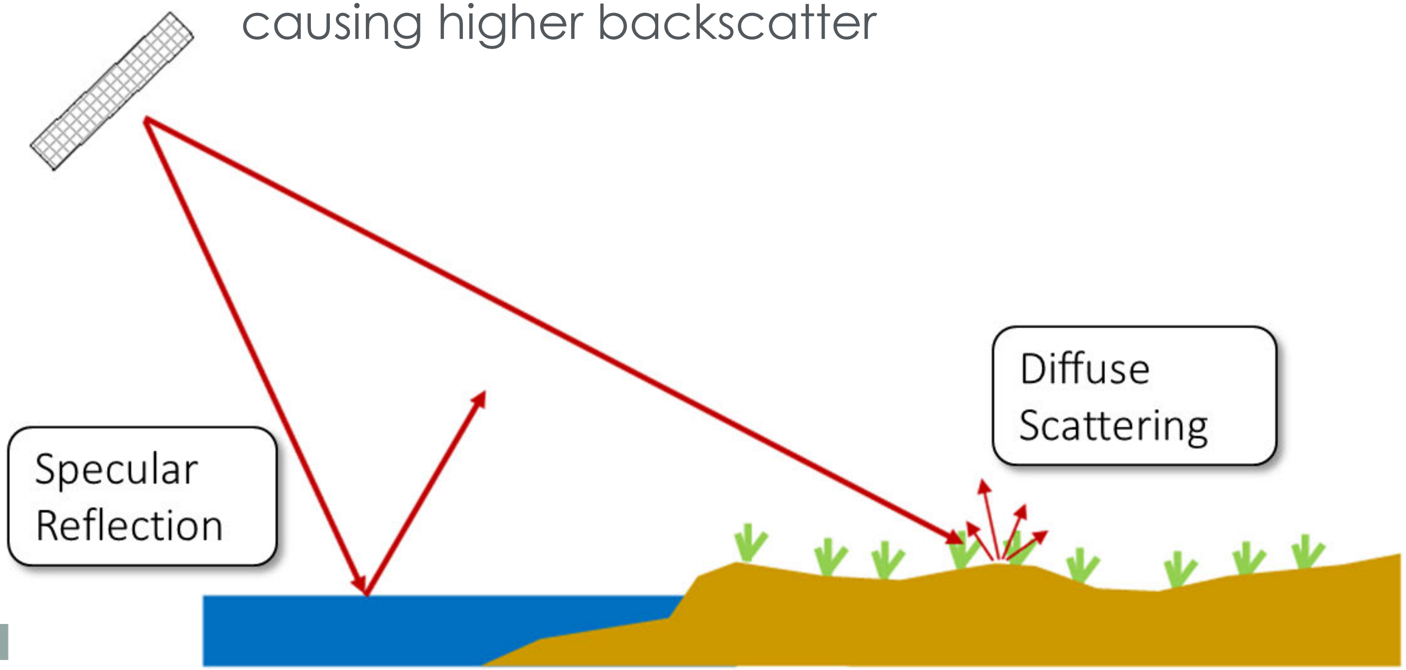




Threshold-Based Surface Water Mapping – The HydroSAR HYDRO30 Approach

Surface Water Signatures in SAR Amplitude Images

- **Mapping of water surfaces based on different radar signatures of water and land**
  - Calm water surfaces appear smooth and cause specular reflection, leading to low backscatter
  - Surrounding land surface appears much rougher, causing higher backscatter



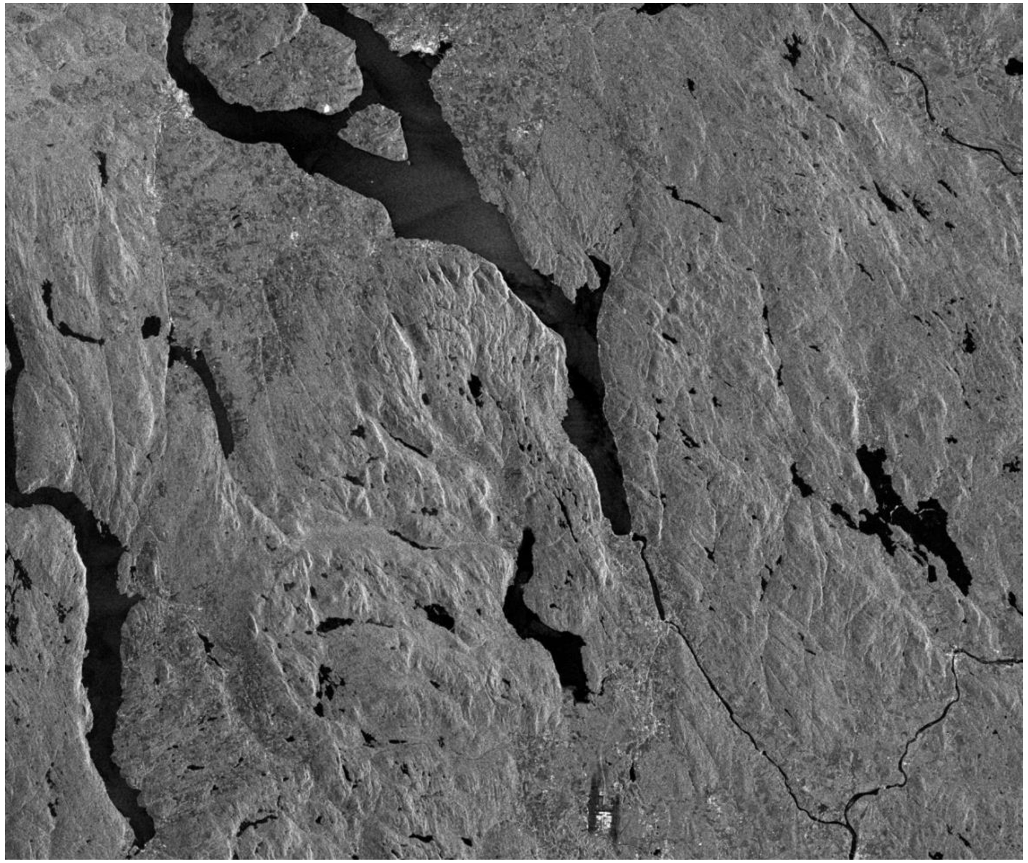


Fig.: Lake Mjosa, Norway, observed by ENVISAT ASAR Image Mode, 12 Dec 2003 (©ESA Multimedia Gallery)

Threshold-Based Surface Water Mapping

The HydroSAR HYDRO30 Approach

- **One simple and common method for waterbody mapping is thresholding.**
  - Contrast between land and open water surface increases with increasing incidence angle

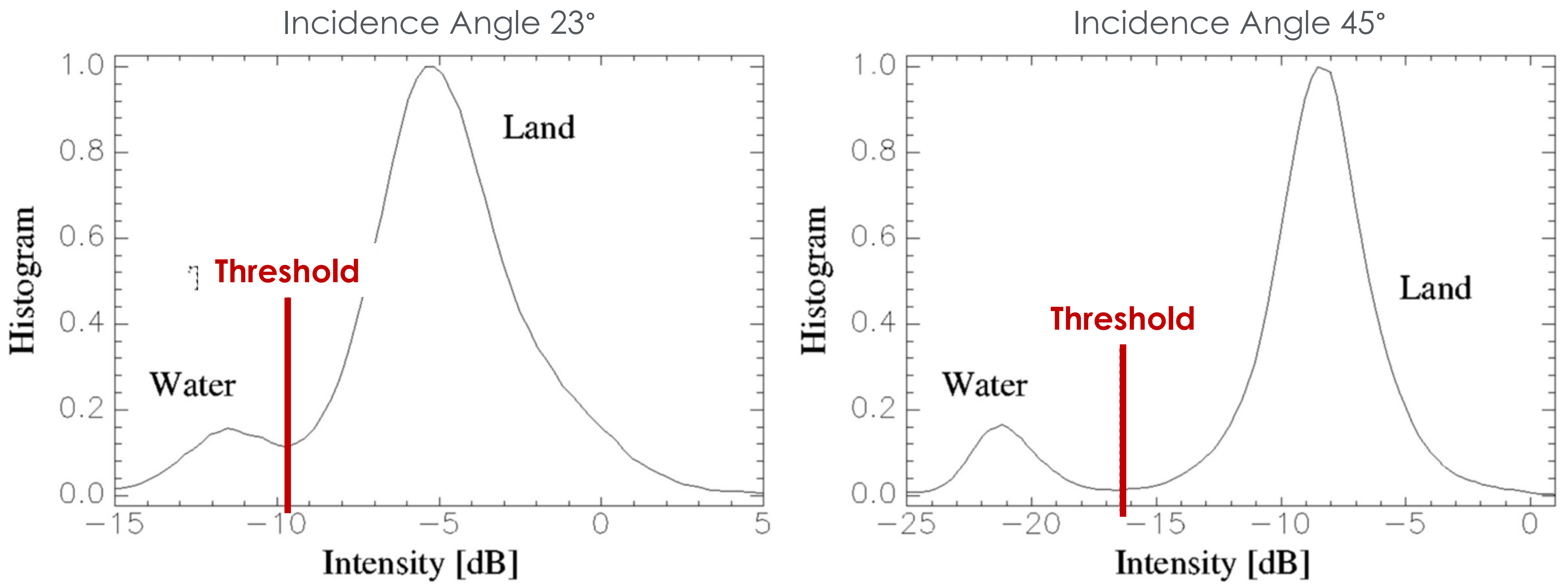
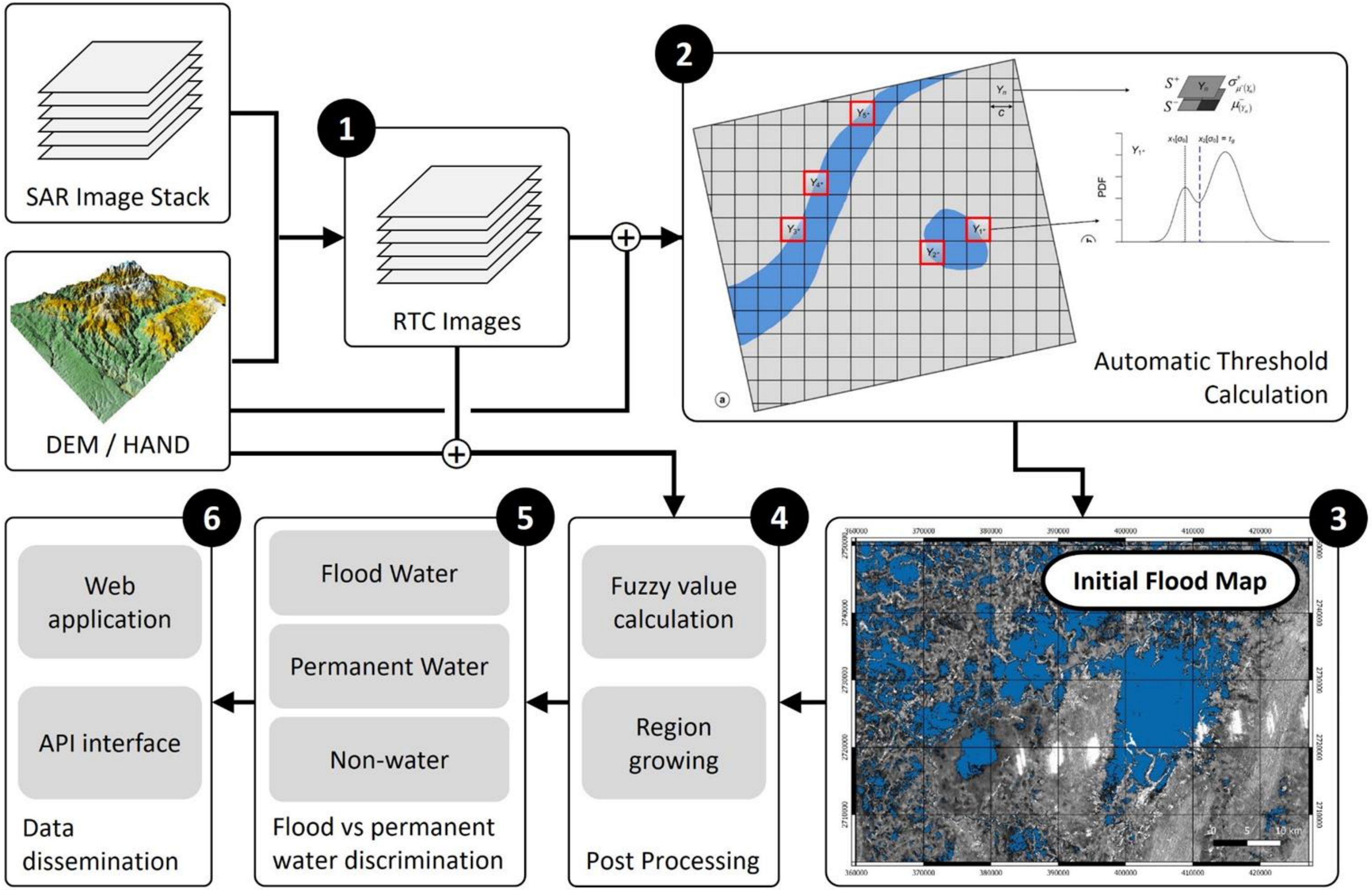


Fig.: Histogram of two Radarsat SAR images of the same region acquired under different incidence angles (Solbø & Solheim, 2004)

HYDRO30: Adaptive Threshold-Based Surface Water Mapping

HydroSAR 6-Step Water Mapping Approach:

1. Image Geocoding and Calibration
2. Automatic & Adaptive Threshold Calculation
3. Flood Candidate Identification
4. Post-Processing to Remove False Alarms
5. Permanent Water Extraction
6. Data Dissemination



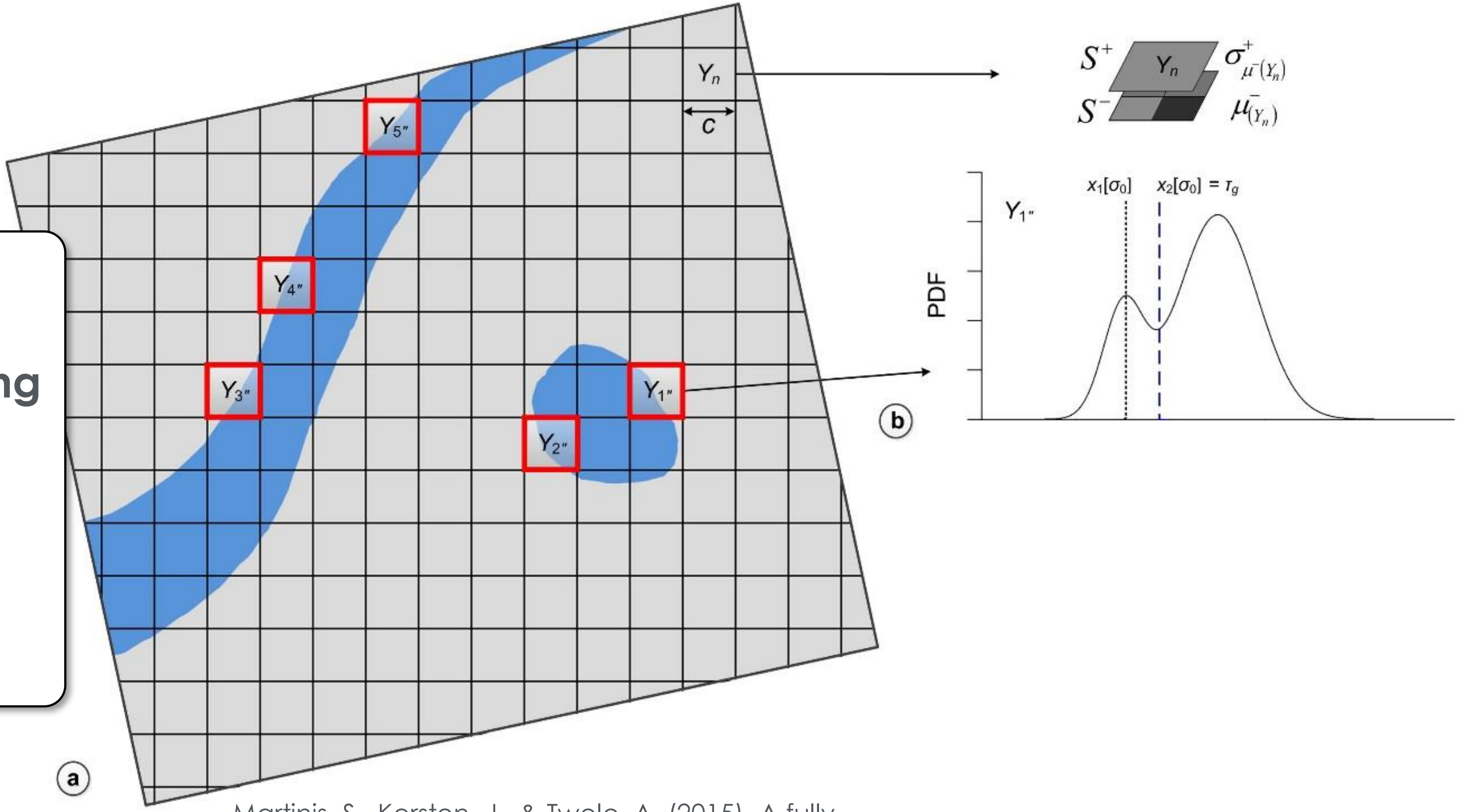
Modified from: S. Martinis et al. "A fully automated TerraSAR-X based flood service." *ISPRS Journal of Photo. & RS* 104 (2015): 203-212.

Adaptive Threshold-Based Water Mapping

Step 2: Automatic and Adaptive Threshold Calculation

Tile image and select pivotal tiles (best tiles for threshold calculation) using

- Tile mean μ_n
- The tile standard deviation σ_n
- Height above nearest drainage $\text{HAND} < 15\text{m}$



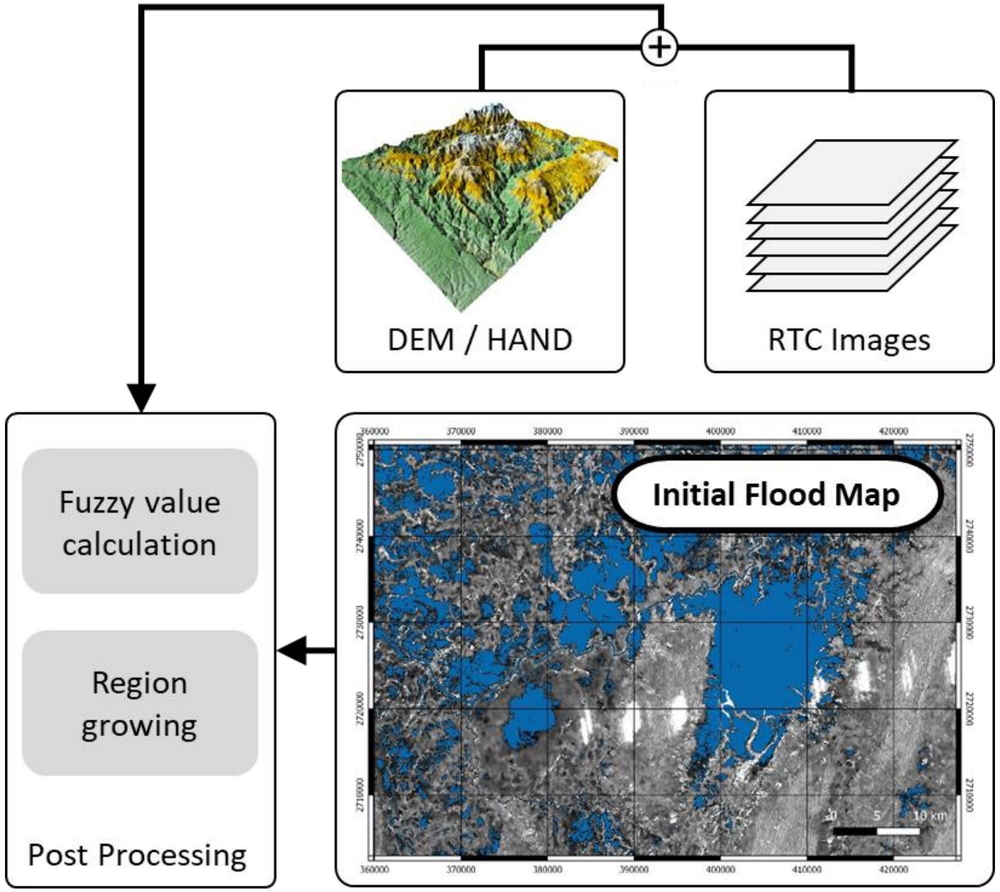
Martinis, S., Kersten, J., & Twele, A. (2015). A fully automated TerraSAR-X based flood service. *ISPRS Journal of Photogrammetry and Remote Sensing*, *104*, 203-212.

Adaptive Threshold-Based Water Mapping

Step 4: Post-Processing to Remove False Alarms

Fuzzy logic rules to remove spurious false detection and improve flood mapping product:

- **Radar Cross Section (RCS) Rule:** Reduces weights for pixels with radar brightness near threshold
- **HAND Elevation Rule:** Low weights for pixels with HAND elevations >> than this average
- **Surface Slope α Rule:** Pixels on slopes receive lower weights
- **Flood Patch Size A Rule:** Very small flood patches receive lower weight



Adaptive Threshold-Based Water Mapping

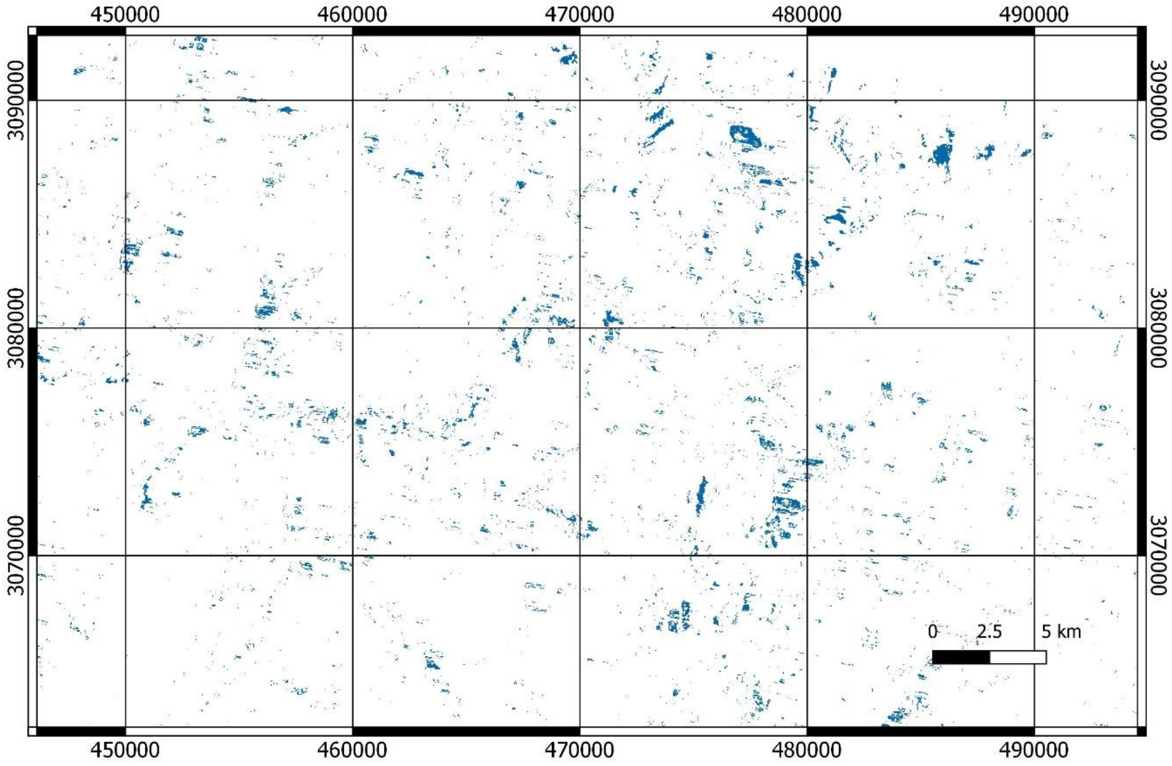
Benefit of Post Processing Steps – Case 1: Mountainous Terrain

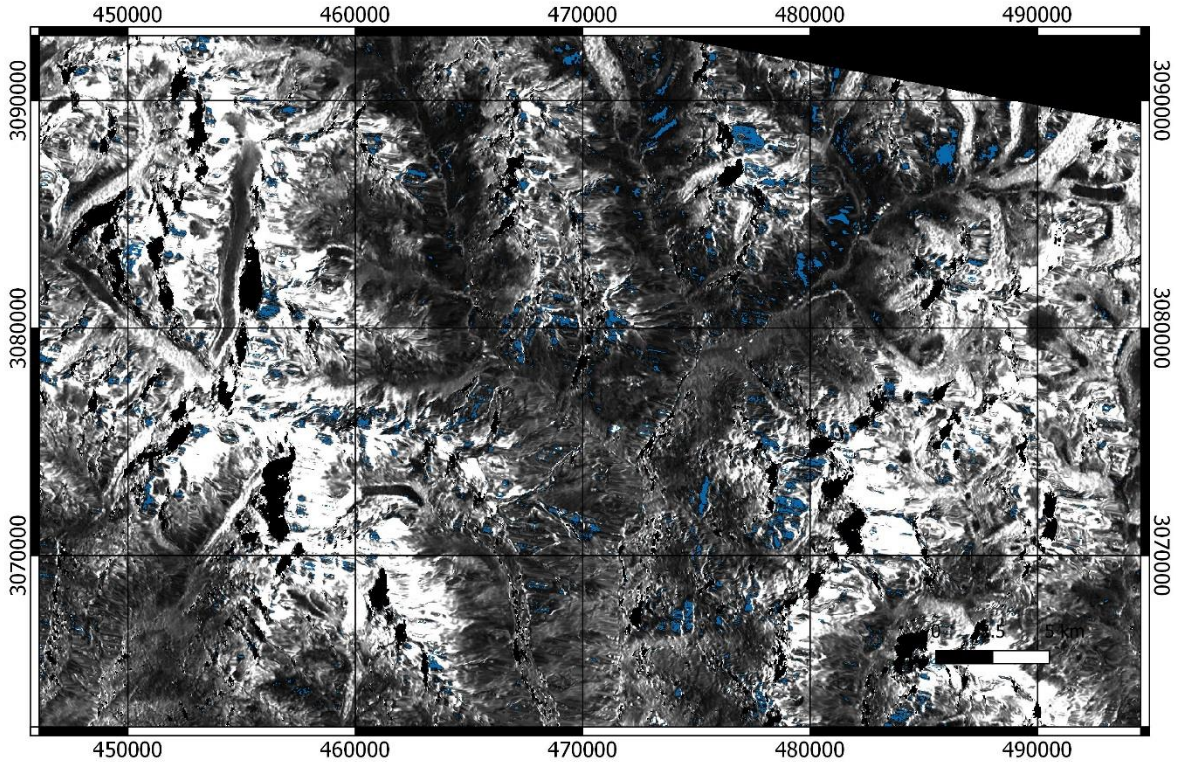
- Mountainous Terrain → Flood look-alikes from layover, shadow, snow, and ice

False alarms due to shadow ice and snow melt

HYDRO30 Product Nepal

No Post-Processing





Adaptive Threshold-Based Water Mapping

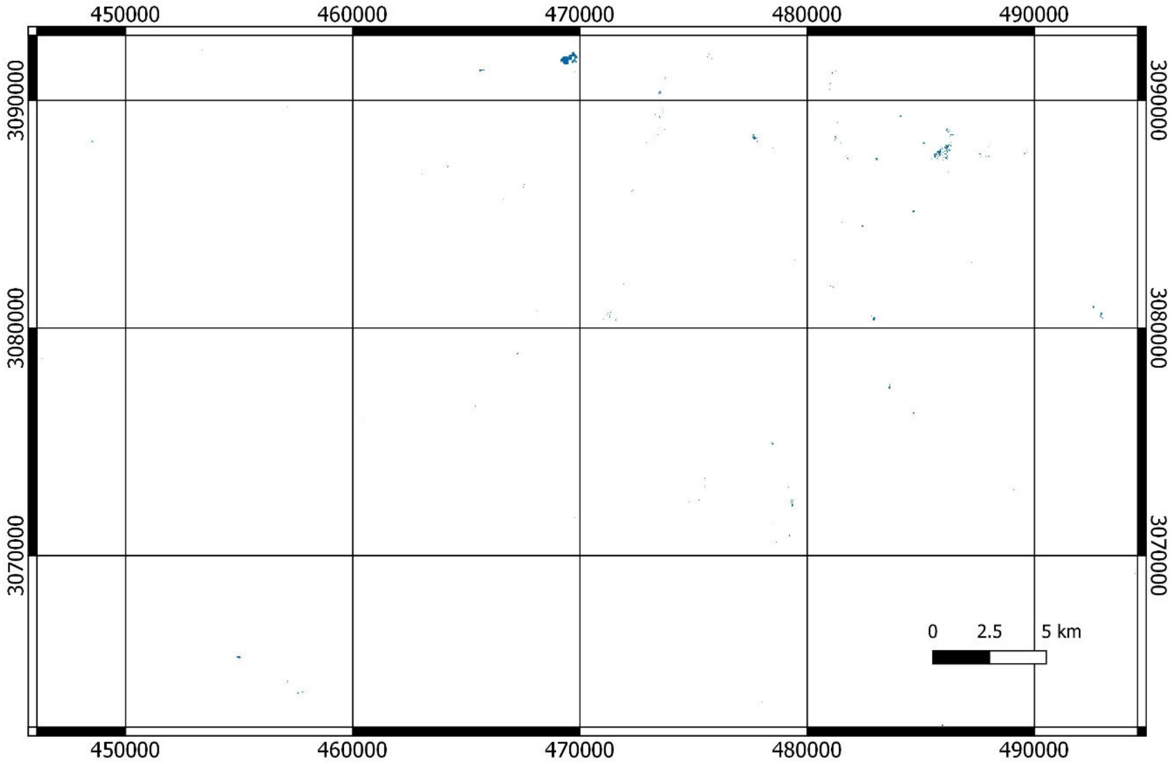
Benefit of Post Processing Steps – Case 1: Mountainous Terrain

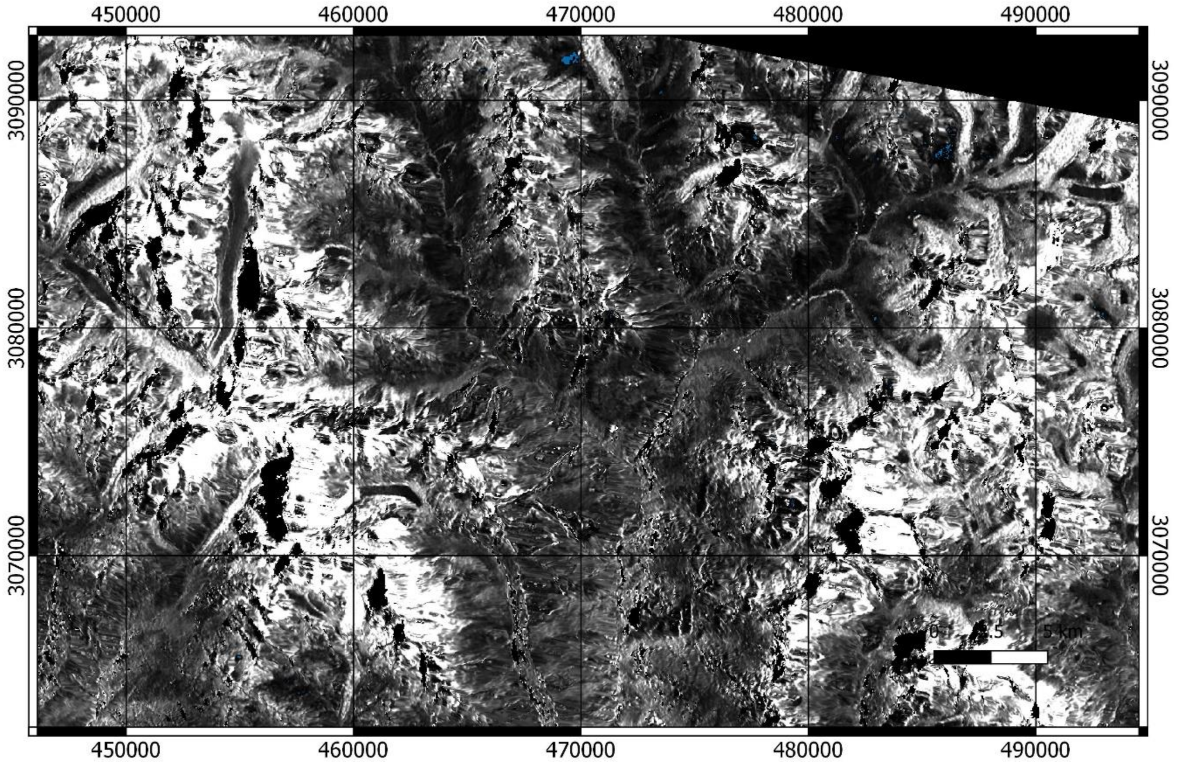
- Mountainous Terrain → Flood look-alikes from layover, shadow, snow, and ice

False alarms removed by Fuzzy Logic post-processing

HYDRO30 Product Nepal

After Post-Processing



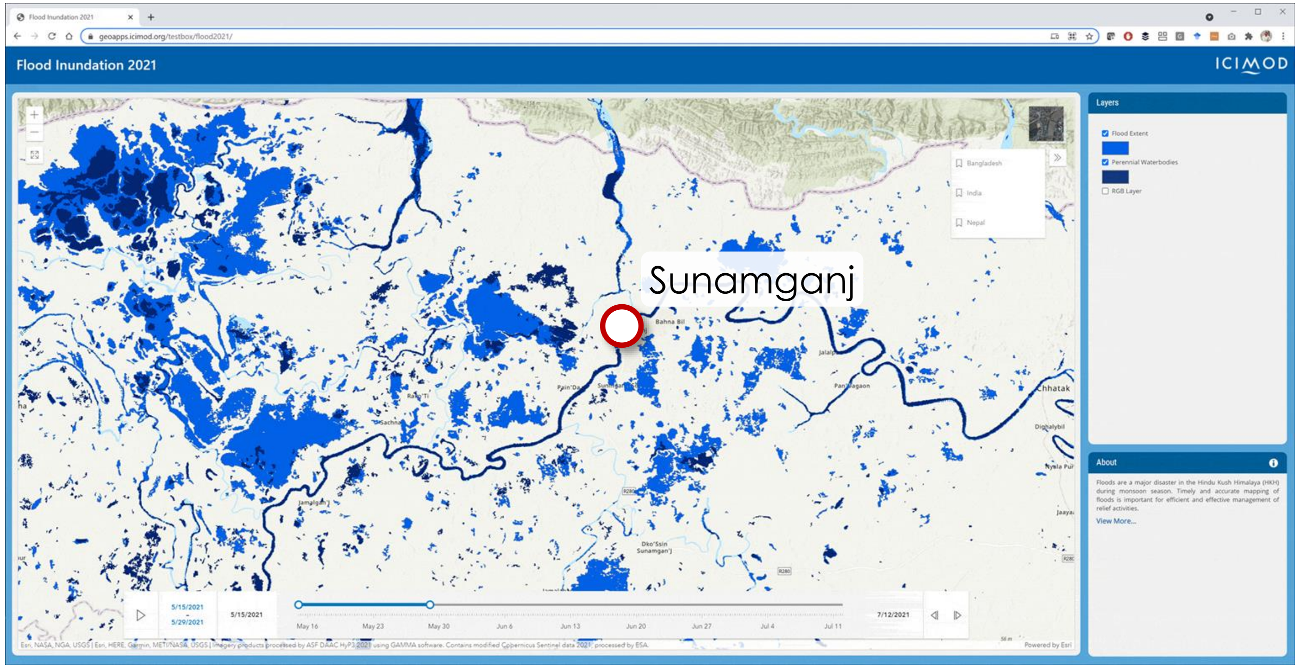


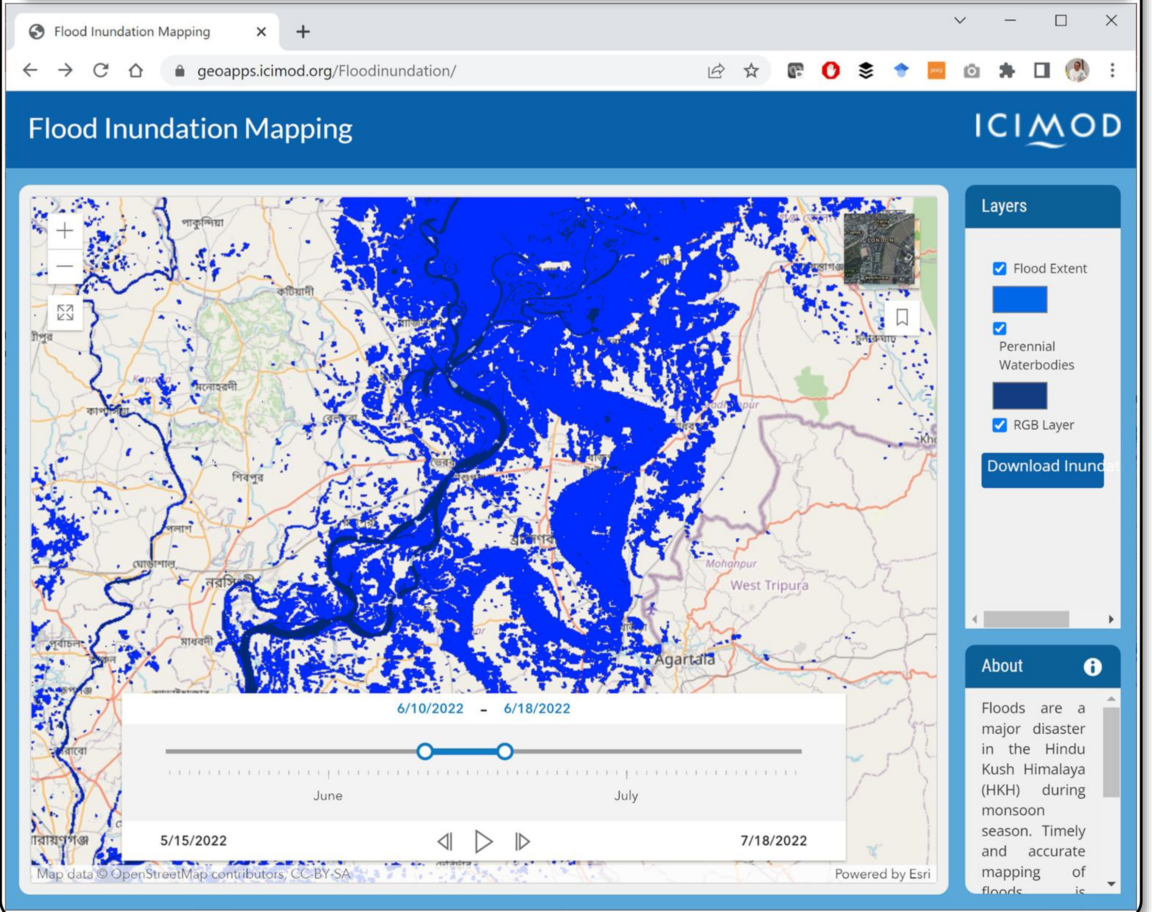
The HydroSAR/ICIMOD Flood Inundation Service

Coverage: Bangladesh, Northern India, Southern Nepal, Southern Bhutan

- Automatically updated **inundation information** with every new satellite pass
- **Permanent water layer** included
- Optional: Visualize SAR background images

Example: Inundation Time Series Near Sunamganj, Bangladesh

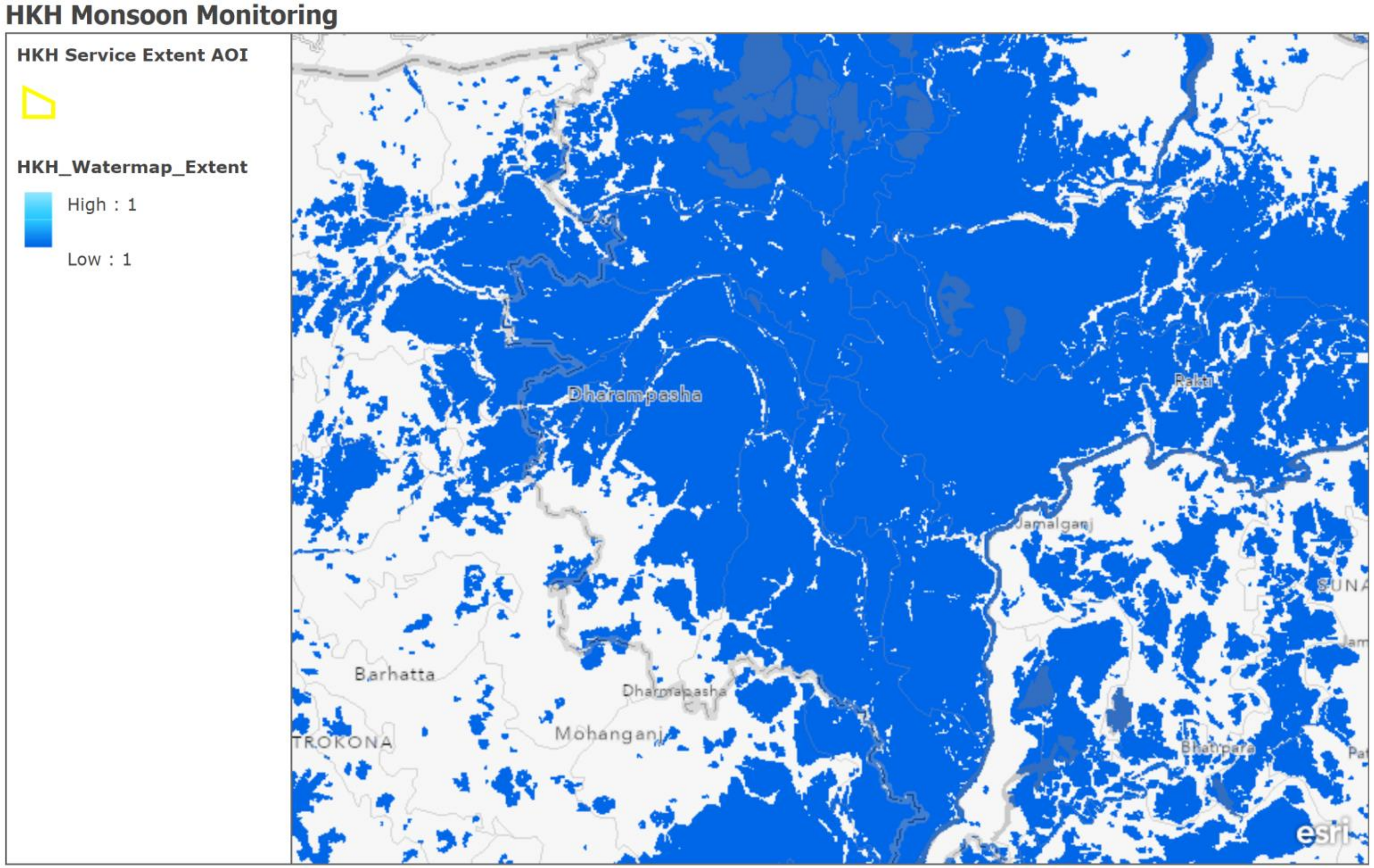




Application: Low-Latency Flood Response

2022 HKH Monsoon Status: Northern Bangladesh, May 22, 2022

An aerial photograph shows a large flooded area following heavy rains in Companiganj, Bangladesh. [AFP]



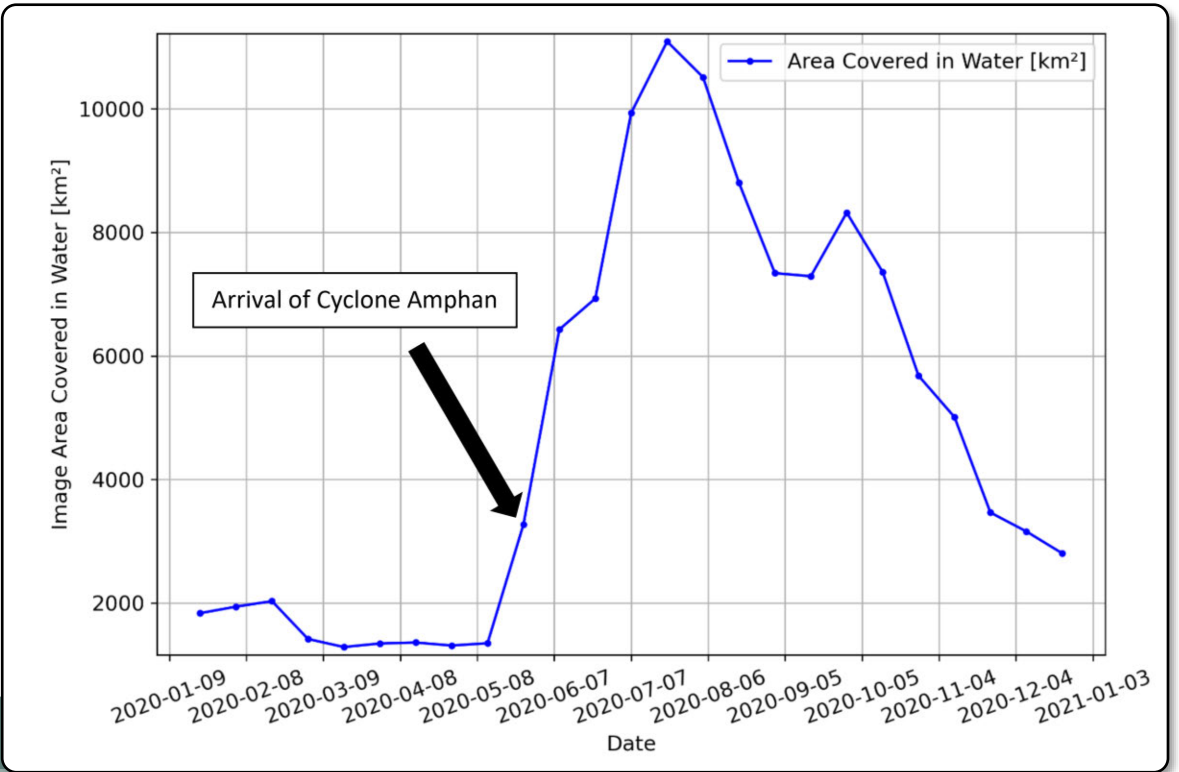
This map displays RTC VV and VH products, RGB Decomposition products, and Water Extent products generated by ASF.

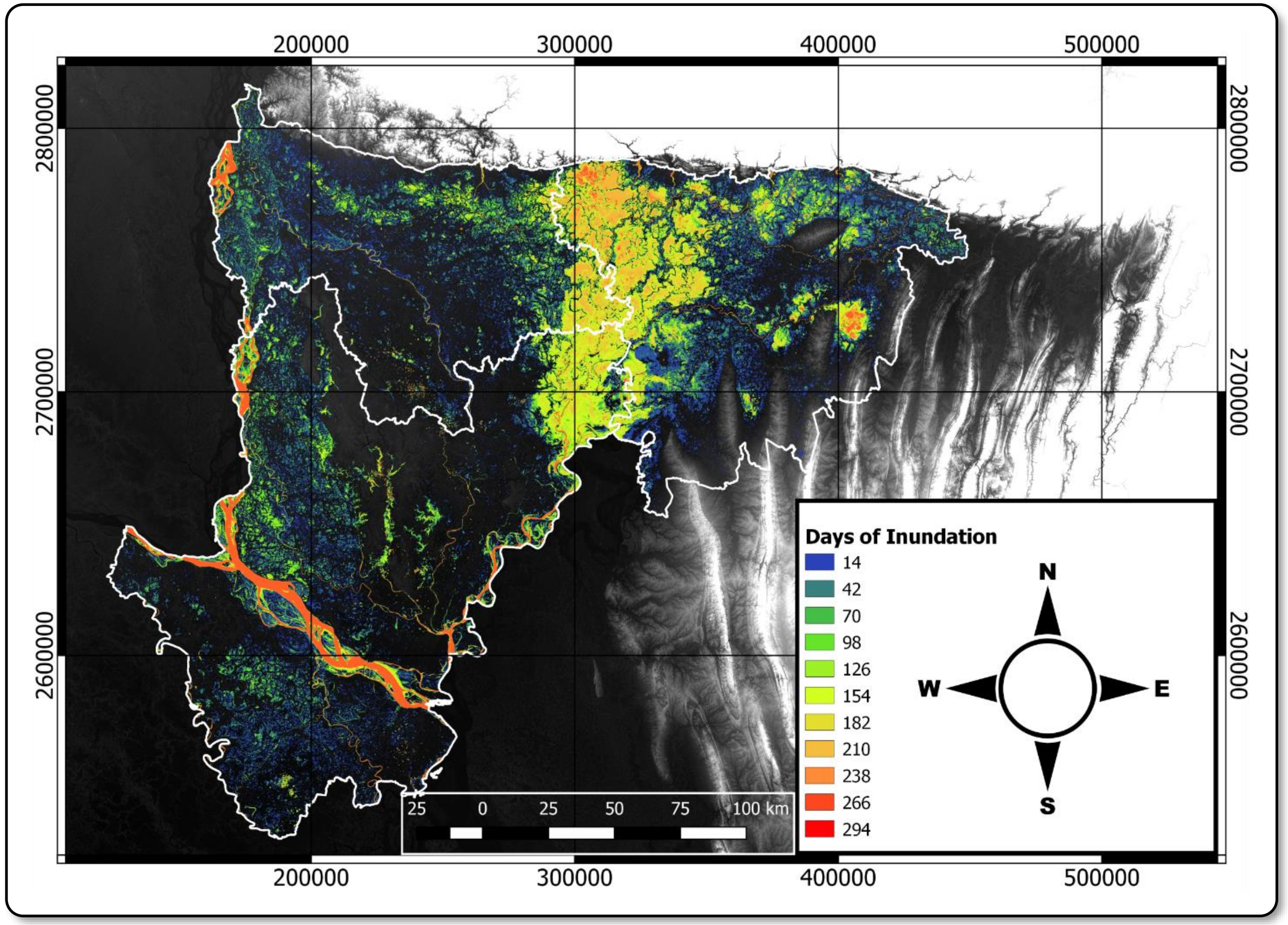
RTC products processed by ASF DAAC HyP3 2022 using GAMMA software. Contains modified Copernicus Sentinel data 2022, processed by ESA. | Imagery products processed by ASF DAAC HyP3 2022 using GAMMA software. Contains modified Copernicus Sentinel data 2022, processed by ESA. | Alaska Satellite Facility | Esri, HERE, Garmin, METI/NASA, USGS | Esri, HERE, Garmin, METI/NASA, USGS | Esri, HERE, Garmin, METI/NASA, USGS

Application: Retrospective Flood Analysis

2020 Flood Analysis of Bangladesh Provinces

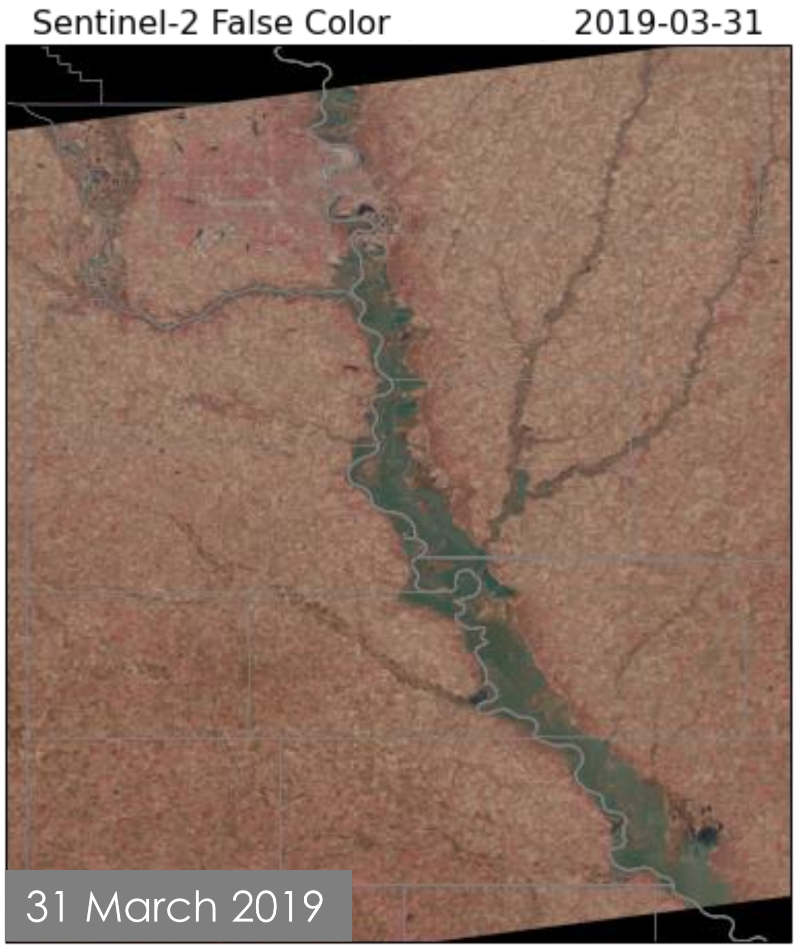
- Analysis of the 2020 flood season in the Sylhet, Mymensing, and Dhaka provinces of Bangladesh
- Maximum flood extent in late July 2020
- Some areas inundated up to 200 days

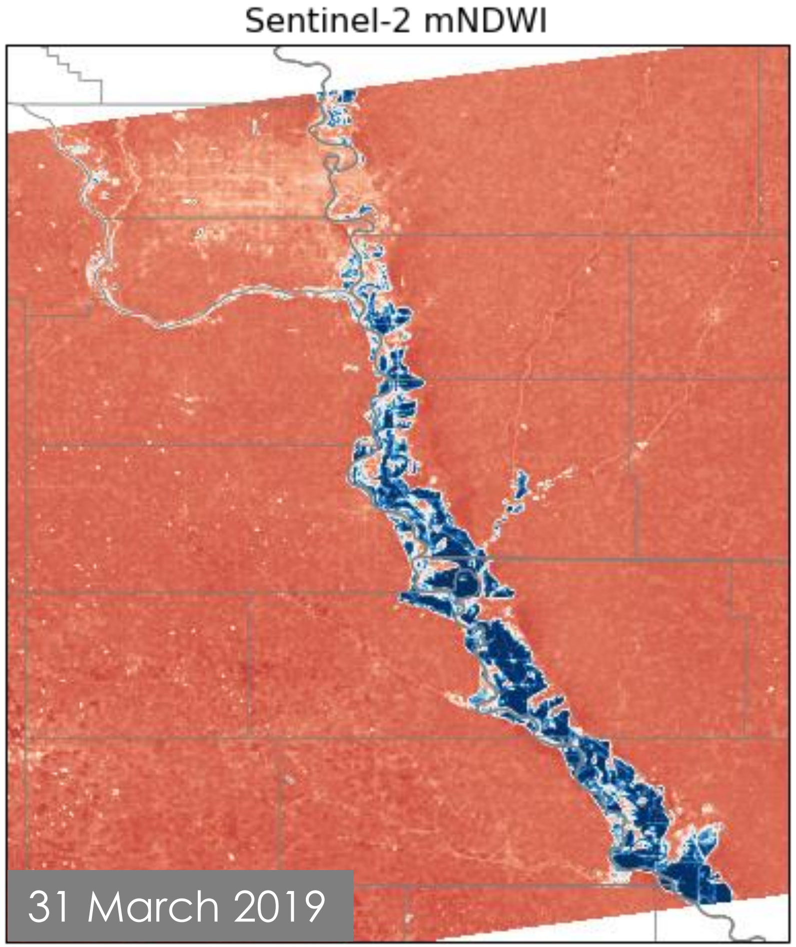


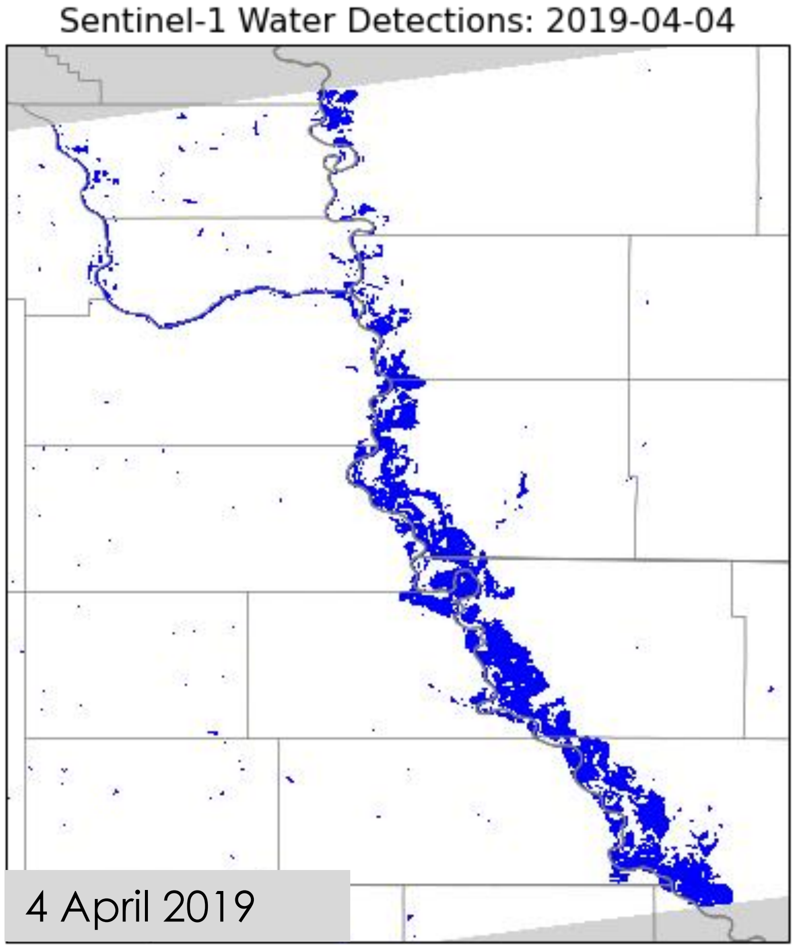


A Word On Water Map Validation

Comparing HYDRO30 to Water Maps from Sentinel-2



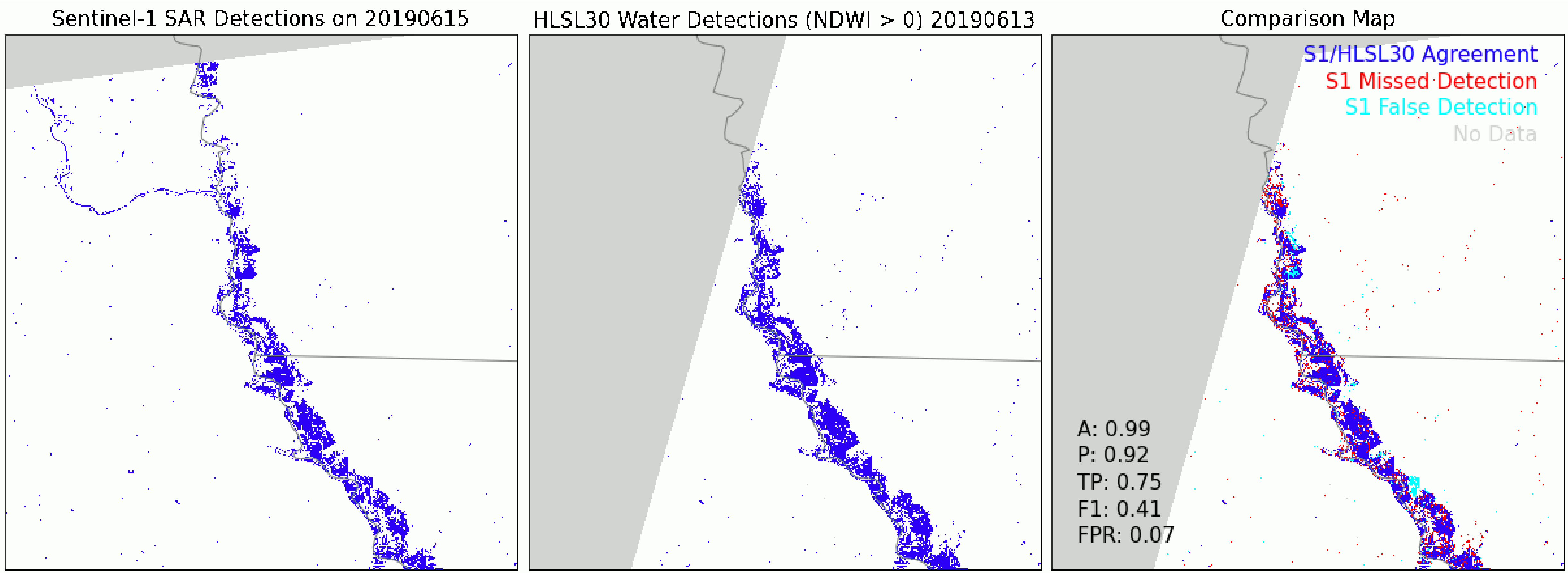




A Word on Water Map Validation

Comparing HYDRO30 to Water Maps from Sentinel-2

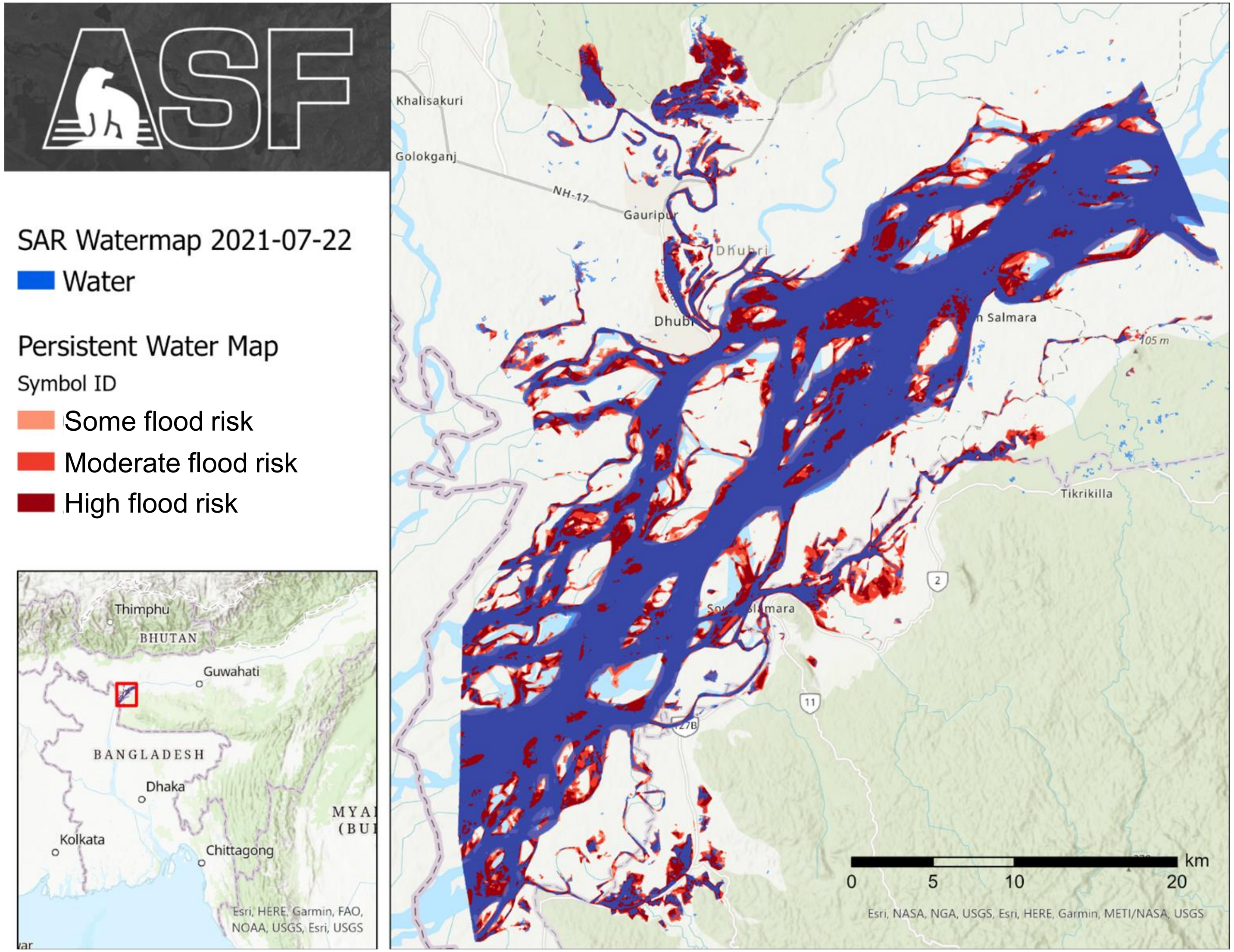
Missouri River Example: More Comparisons of HYDRO30 and Near-Simultaneous Sentinel-2 Data



Validating Your Water Extent Map

Comparing HYDRO30 Products to Google Flood Forecasts

- **Comparison of HYDRO30 and Google Flood Forecast near Dhubri, Assam, India**
  – Comparison shows consistent features with forecasted flood extent slightly larger



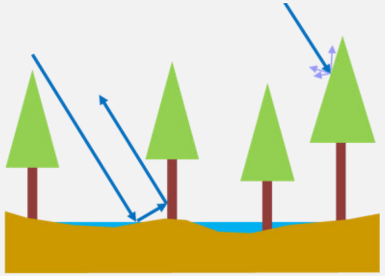
Limitations of Threshold-based Surface Water Mapping

Sensor-Based Limitations

Wind Roughness on Water

- **Problem**: Increases radar brightness and may prevent water detection
- **Mitigation**: Use VH in addition to VV for water detection

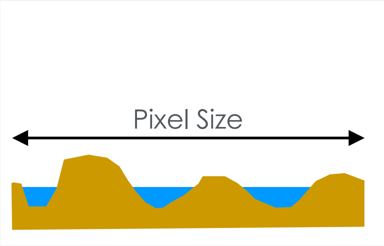
Water Under Dense Vegetation



- **Problem**: Radar may not be able to penetrate vegetation
- **Mitigation**: Use longer wavelength radar (e.g., NISAR)

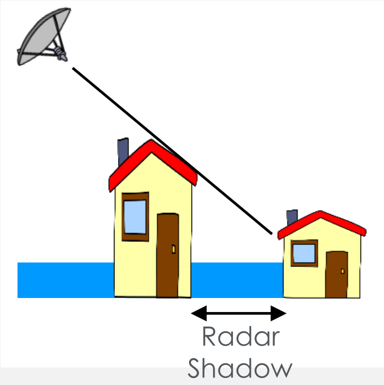
Environmental Limitations

Partially Inundated Pixels



- **Problem**: Pixels are not dark enough for detection
- **Mitigation**: Higher-resolution radar or combine with change detection approach

Water in Urban Environments

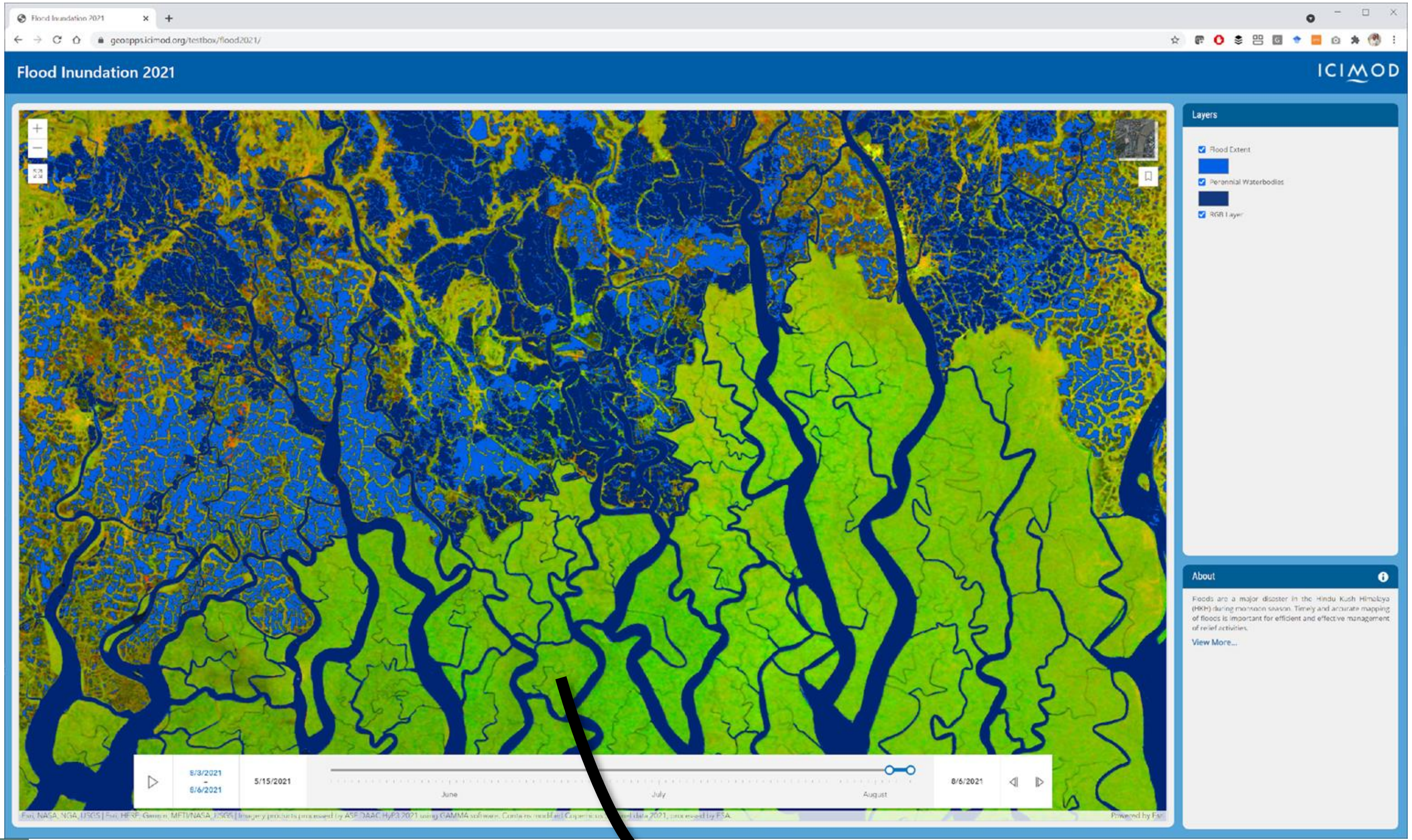


- **Problem**: Due to side-looking geometry, buildings obstruct surface water from view
- **Mitigation**: Use multiple viewing geometries – use optical data

Limitations of Threshold-based Surface Water Mapping

1. Missed Detections in “Water Under Vegetation” Areas

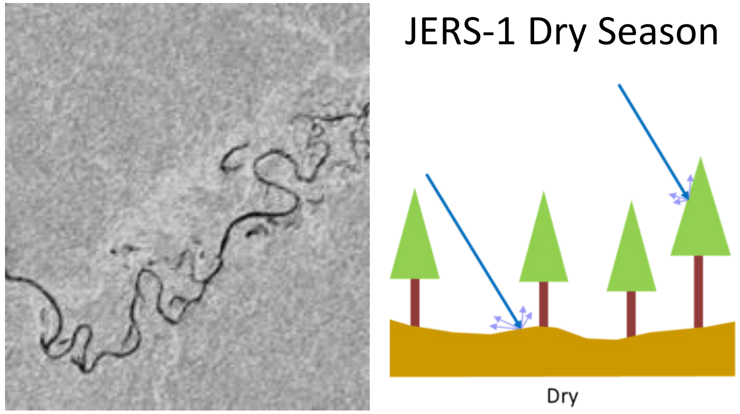
Flood Water Detections — Permanent Water Map

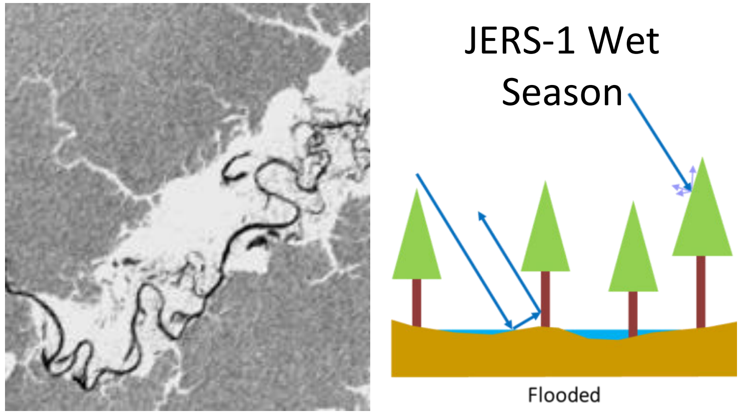


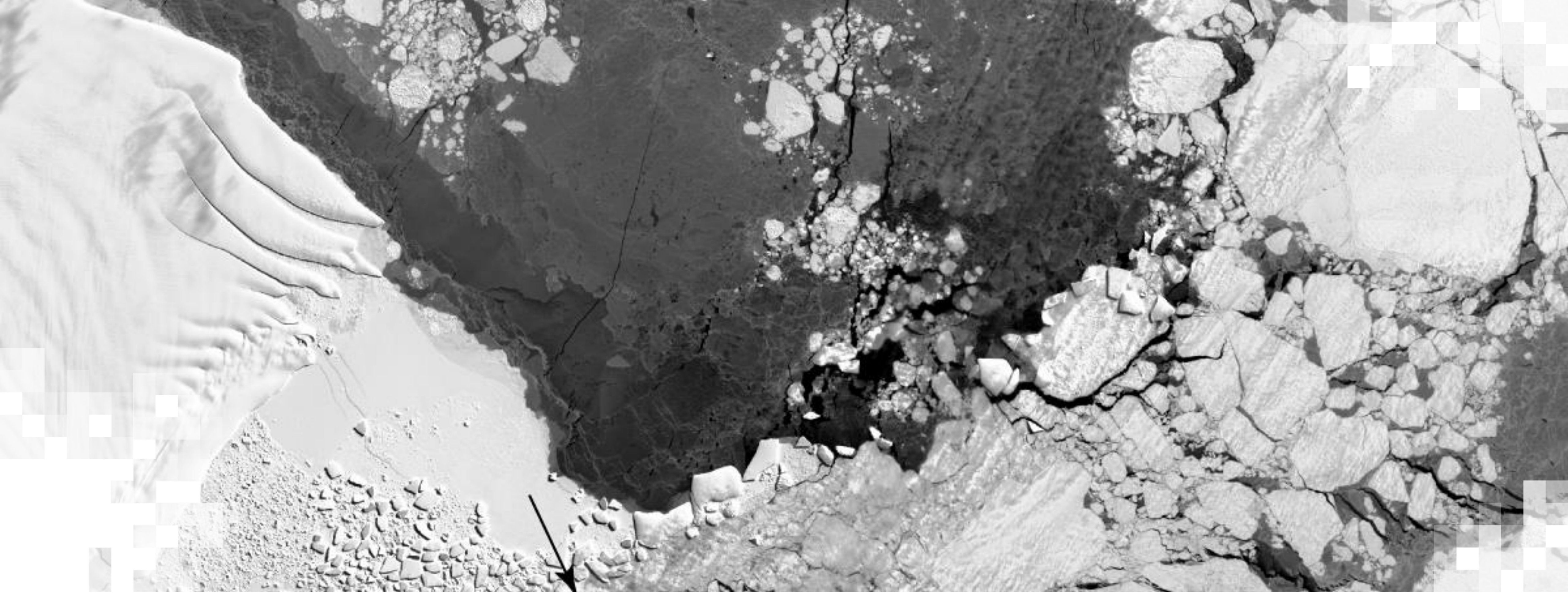
Missing Water Detections in Mangrove Forest

Additional Note:

At L-band (NISAR) water under vegetation shows up as bright areas in the image.



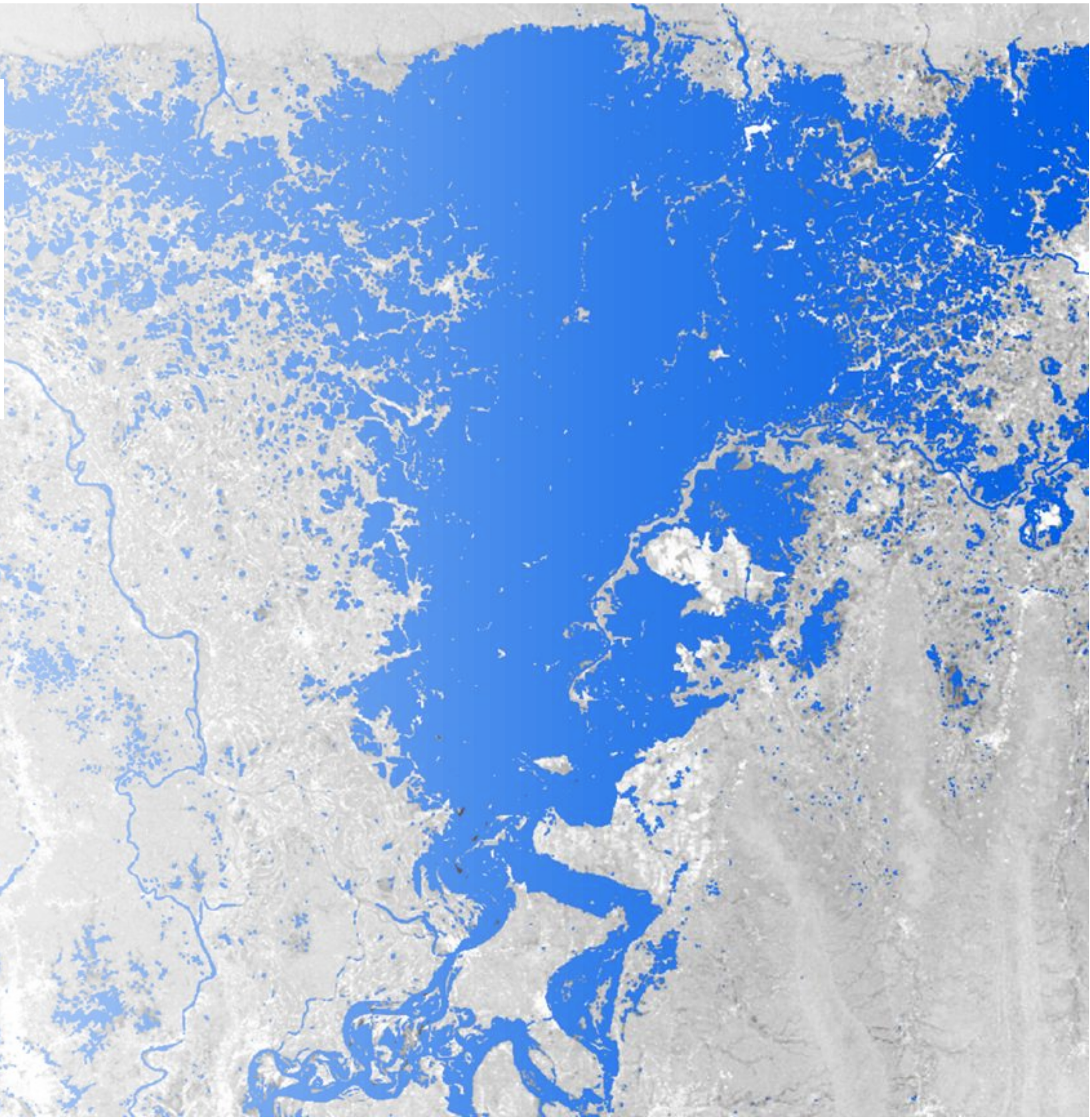




A Jupyter Notebook-Based Surface Water Mapping Exercise

Lab: Flood Extent Mapping using the HYDRO30 Notebook

To conduct this lab exercise, please launch the HYDRO30 notebook via Binder:
https://mybinder.org/v2/gh/ASFBinderRecipes/Binder_SAR_Hazards_Floods/main?labpath=SARHazards_Lab_Floods.ipynb



launch binder

jupyter

binder

Summary

- Globally- and regularly-acquired data from Sentinel-1 and NISAR are an excellent basis for hazard monitoring applications.
- SAR has excellent abilities to map surface water in all weather conditions.
- Threshold algorithms are able to provide automatic water mapping capabilities.
- L-band SAR data will provide improved ability to map water under vegetation.
- Several public water mapping services exist these days taking advantage of the capabilities of SAR.

Acknowledgements

- Thanks to **Copernicus**, the **European Space Agency**, and the **NASA Alaska Satellite Facility DAAC** for access to Sentine-1 SAR Data.
- Thanks to **NASA SERVIR** for funding the HydroSAR development efforts.
- Thanks to **Thomas Meyer**, **Lori Schultz**, and others for contributions.

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- ARSET Website
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Relevant Literature

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Links to Selected Existing and Upcoming SAR-Based Water Mapping Services

- HydroSAR Flood Mapping Service for the Hindu Kush Himalaya
- OPERA Dynamic Surface Water Extent Product Information
- Copernicus GloFAS Global Flood Monitoring (GFM) Service
- HYDRAFloods (HYDrologic Remote Sensing Analysis for Floods)

Thank You!